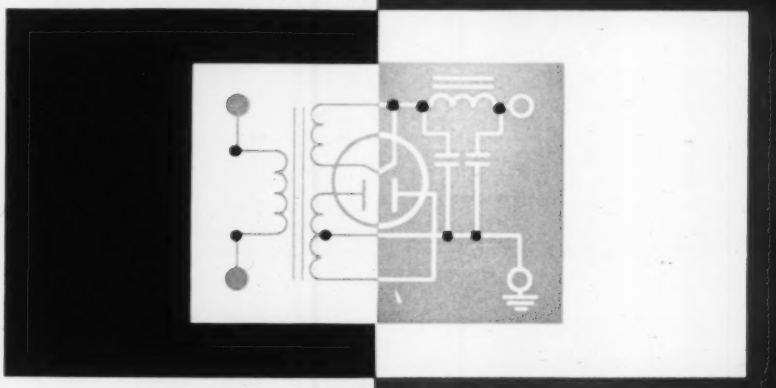
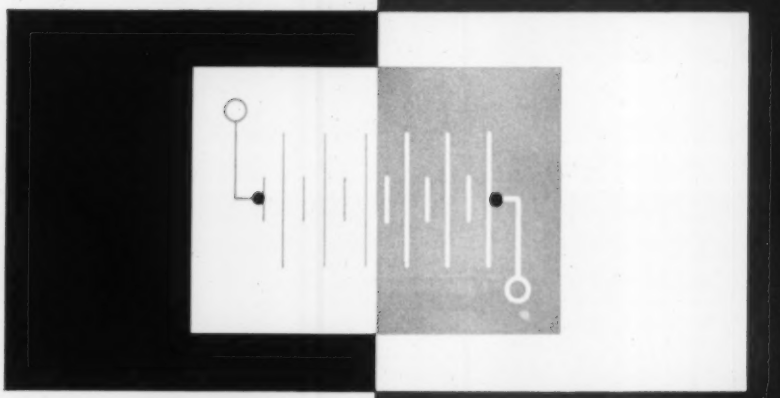
MAY 29, 1958

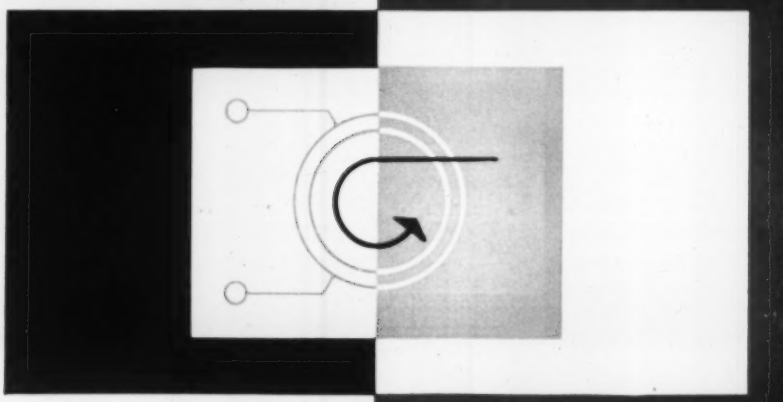
MACHINE DESIGN

A PENTON PUBLICATION — BIWEEKLY





Electric Power Supplies



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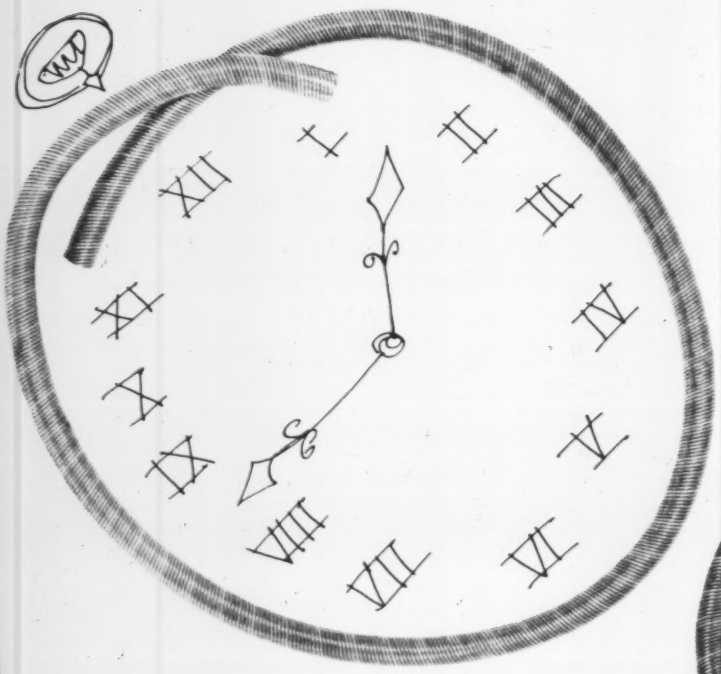


S.S.White FLEXIBLE SHAFTS

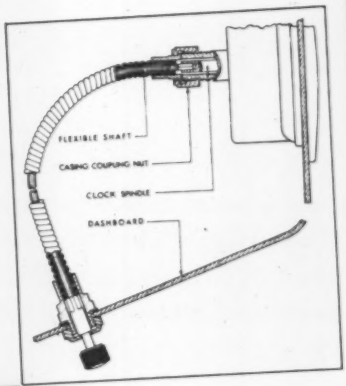
save time, trouble and money

Save time by designing your remote controls and power drives with S.S.WHITE FLEXIBLE SHAFTS. Selecting an S.S.WHITE FLEXIBLE SHAFT is a simple, easy matter. You can choose the right one for any application from a wide range of Standard "off-the-shelf" units, pre-engineered units or custom-engineered units. Since a single S.S.WHITE FLEXIBLE SHAFT may replace a complicated system of gears, pulleys and belts, you'll also save considerable design and layout time, too.

Save trouble by using quality-built S.S.WHITE FLEXIBLE SHAFTS in your equipment. Our years of experience in the design, manufacture, and application of flexible shafts to hundreds of different products assures you of getting the best possible shaft for your need.

Save money by using S.S.WHITE FLEXIBLE SHAFTS to replace expensive parts needed to carry power and control around turns. You also save by simplifying assembly and by saving space.

A typical example of the time-, trouble- and money-saving advantages of an S.S.WHITE FLEXIBLE SHAFT is shown at the right. In this auto clock-setter, the shaft makes a 90° bend – gives full freedom in locating both the clock and the knob wherever desired – without the use of gears and without the need for accurate alignment of solid shafts.



S.S.White

FIRST NAME IN FLEXIBLE SHAFTS

USEFUL DATA on how to select and apply flexible shafts! Write for Bulletin 5601.

S.S.White Industrial Division, Dept. 4, 10 East 40th St., New York 16, N. Y. Western Office: 1839 West Pico Blvd., Los Angeles 6, Calif.

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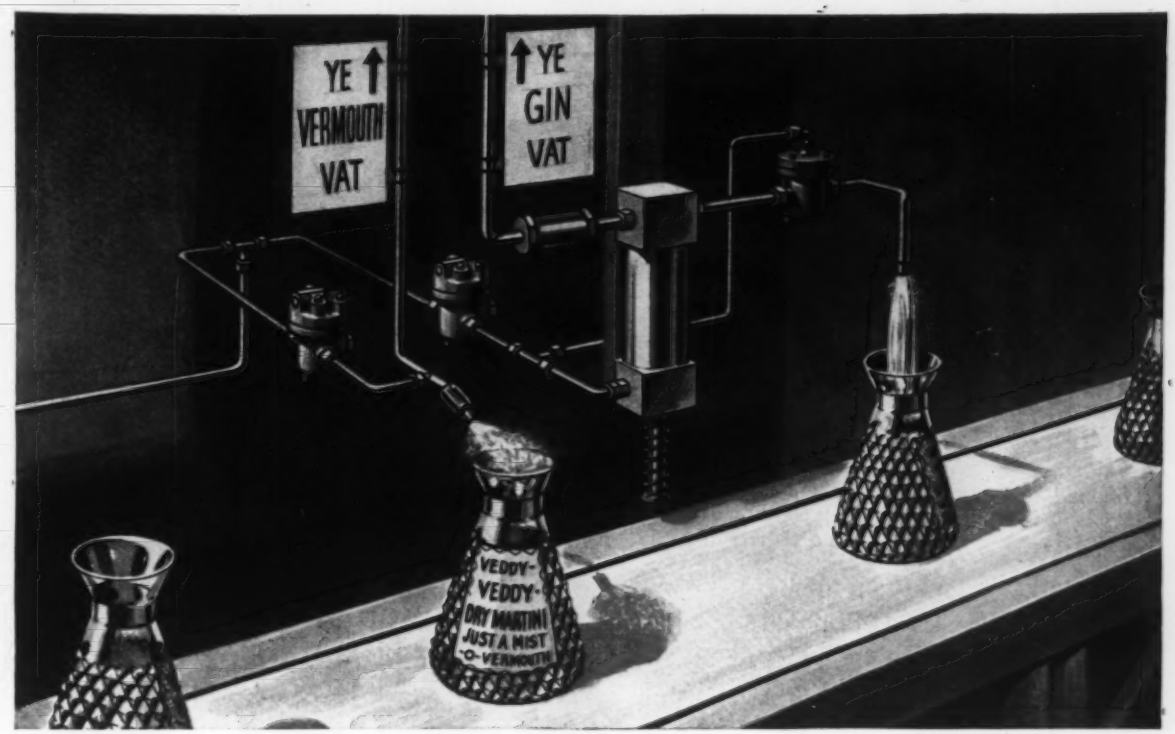


What? Air Automates the Extra, Extra-Dry Martini!

The ready mixed Martini may never come to this but . . .

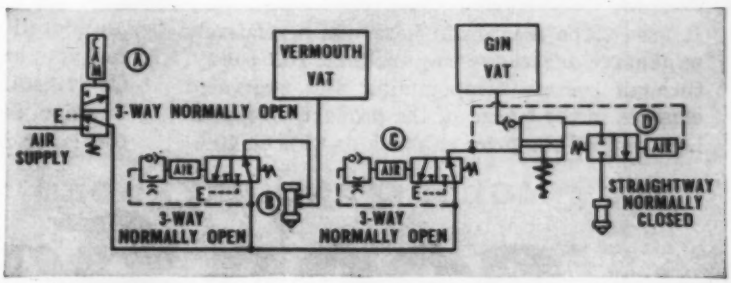
"Don't bruise the Vermouth!" Maybe you subscribe to the idea of only a fog of Vermouth or maybe you like yours four-to-one. But, if it came to bottling this vogue-ish mixture, the circuit here could certainly do it. Meanwhile it gives us a fanciful way to show you how you can easily create an all air circuit that does a continuous sequence of timed operations by using valves that can be both operated and sequenced by air. Every time the conveyor stops, it triggers the circuit.

Triggering one operation with another and timing the operating periods—all with air—may save the day for you.

The same air involved in the main operation can also pilot these valves. What's more these valves can be preset to wait out a time delay before operating, or operate for a self-measured time. Using them you can create unlimited all-air automation systems which could just turn the trick where you wish to avoid electricity, or want to stick with just one power medium.

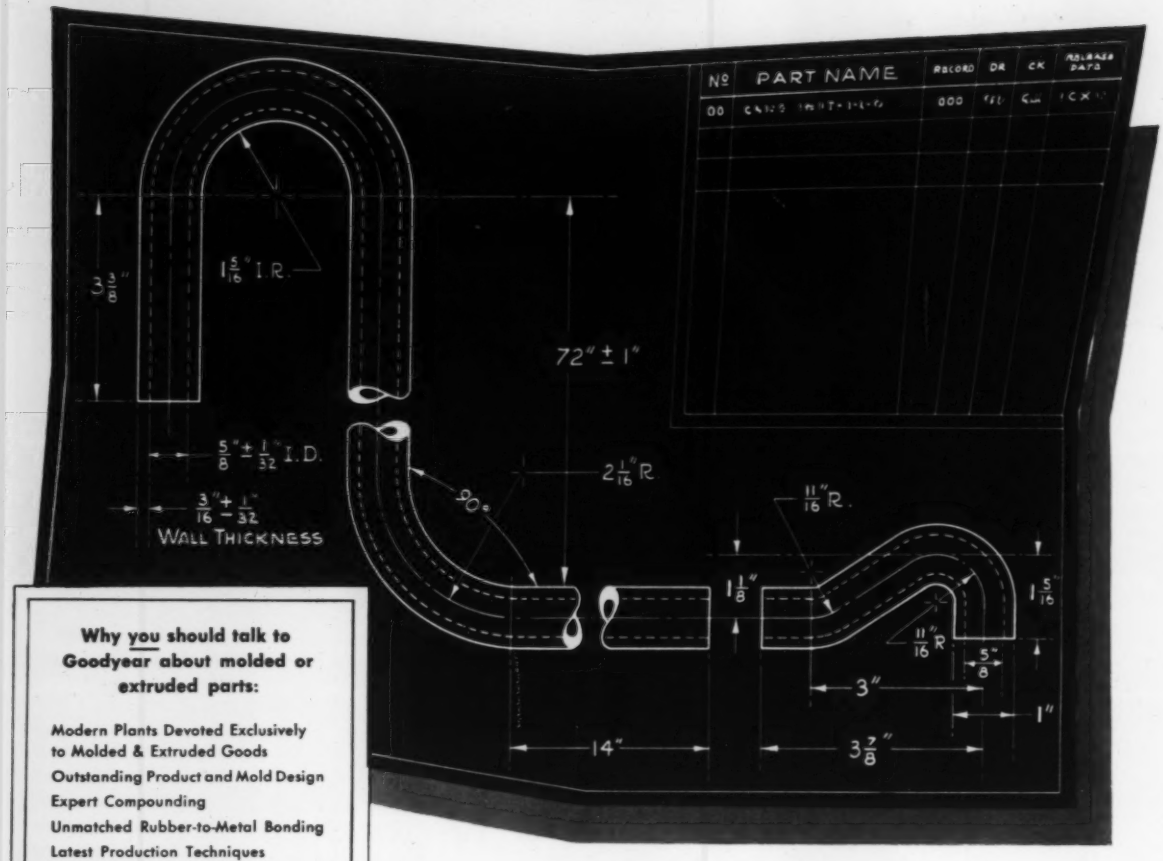
SEQUENCE OF OPERATION

1. Conveyor indexes, opening cam valve (A). This introduces air to valves (B) and (C) which begin timing out. Vermouth is atomized by Vermouth nozzle, cylinder expels a measured amount of gin through master valve (D) which has been opened by air from the outlet of valve (C).
2. Valves (B) and (C) time out and close, stopping liquid flow.
3. Conveyor indexes again.



ROSS OPERATING VALVE CO. **109 East Golden Gate • Detroit 3, Michigan**

Blueprint for "cost reduction #EM-581"



Why you should talk to Goodyear about molded or extruded parts:

- Modern Plants Devoted Exclusively to Molded & Extruded Goods
- Outstanding Product and Mold Design
- Expert Compounding
- Unmatched Rubber-to-Metal Bonding
- Latest Production Techniques and Equipment
- Skilled Production Personnel
- Audited Quality Control

On drain hose—costs cut up to 40%

Detailed above is one of the many types of washing machine drain hose made by Goodyear for leading appliance manufacturers. Behind this part lies a story of savings which is typical of much of the molded and extruded rubber and plastics goods that flow from the modern Goodyear plants at St. Marys, Ohio, and Los Angeles, California.

It used to be that drain hose was a relatively expensive accessory to purchase. But today, through custom compounding and suggested changes in the design of the product, Goodyear has dropped the price as much as 25% to 40%.

What's more, the need for resistance to heat, water, detergents, flexing and age has been fully met, the quality of product actually improved.

The reasons why Goodyear can and does effect cost reductions on many types of molded and extruded rubber goods are listed in the panel above. If you would like more information or an invitation to visit one of the plants, just contact your local G.T.M.—Goodyear Technical Man. Or write direct to Goodyear, Industrial Products Division, St. Marys, Ohio, Los Angeles 54, California, or Akron 16, Ohio.

MOLDED AND EXTRUDED GOODS BY

GOODYEAR

60

THE GREATEST NAME IN RUBBER

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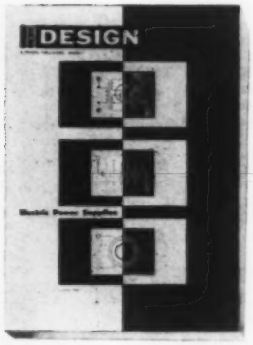

Front Cover: Three types of electric power supplies—an electronic rectifier, a battery, and an electric generator—are featured by artist George Farnsworth to keynote the special section on "Electronic and Electric Power Supplies" that begins on Page 99 of this issue.

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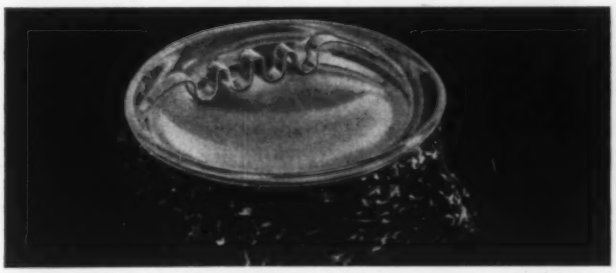
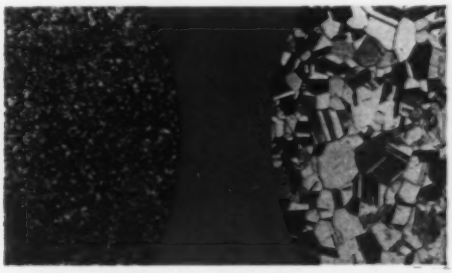
NEW BRASS SPEEDS FINISHING operations for Park Sherman Co.—Formbrite, Superfine-Grain Drawing Brass by Anaconda, reduces polishing time—cuts cost up to 50%—gives clean, easy formability.

TO THE PARK SHERMAN CO., Springfield, Ill., finishing operations are important in giving its line of fine brassware sales appeal—are also weighty cost factors. Switching from ordinary drawing brass to Formbrite, Park Sherman boosted production on the tray of this "Merry-Go-Round" Bar—25% in the cutting operation—42% in finish buff.

THE COVER of this Park Sherman Silent Butler is now made of Formbrite, Anaconda's Superfine-Grain Drawing Brass. Polishing operations in preparation for chromium plating are 50% faster than with ordinary drawing brass.



PRODUCTION INCREASED 47% in finishing operations on this Park Sherman Sta-Put ashtray after the shift to Formbrite. Products shown are only three of many Park Sherman products now made of Formbrite.



THE SECRET of Formbrite's superior polishing characteristics is its superfine-grain. Micrographs (75X): left, Formbrite; right, ordinary drawing brass.

Wherever finishing is an important cost factor in formed or drawn products, Formbrite in sheet and strip is designed to save you money. In brass wire alloys for cold-heading and upsetting, it gives a stronger, springier, more abrasion-resistant product. For more detailed information, write for Publication B-39. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

5848

FORMBRITE®

SUPERFINE-GRAIN DRAWING BRASS

a product of

ANACONDA®

Made by The American Brass Company

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Elaborate Tests Preceded ICBM Nose Cone Development

Heating Problem Simulated By Blasting Missile Downward

SUNNYVALE, CALIF.—The Air Force has fired more than 20 ballistic nose cones into space during the past year—all of which survived the re-entry heat barrier—in test flights leading to design of a suitable nose-cone configuration. A special, three-stage missile, the Lockheed X-17, was used to simulate ICBM re-entry conditions.

Two important techniques were involved in the X-17 program, according to Air Force officials. These were the use of a free-flight approach with the X-17 to simulate conditions that operational missiles would encounter, and the use of telemetering data from the missile during its journey into space, its hypersonic plunge through the atmosphere, and down to impact.

In the test procedure, the three-stage, 40-foot-tall X-17 is blasted into space by the first stage only. After reaching the top of its flight and starting downward into the atmosphere, the first stage is discarded and the second stage fired. This accelerates the missile to a tremendous speed through the earth's atmosphere. When the second stage is exhausted and discarded, the third stage is ignited, driving the missile downward at an even greater speed. During the brief flight, the telemetering system aboard transmits data on speeds, temperature, pressures and other quantities, almost to the instant of impact.

As is now known, the shape of the nose cone was the critical factor in the investigation of the heat barrier problem, and test flights of the X-17 substantiated the theoretical calculations which led to successful nose cone design.

Less than a month ago, the first full-scale nose cone was fired—on a Jupiter IRBM—and recovered intact.

SIX-MAN MULE, built by Willys Motors, is a ¾-ton version of the ½-ton Mechanical Mule now in service with Army and Marine Corps. The new vehicle converts quickly to a cargo carrier by folding seats flush into the platform bed and can also mount the Army's 106-mm recoilless rifle. Like the ½-ton Mule, the new carrier is powered by a Willys four-cylinder, air-cooled aluminum engine mounted under the platform. Top speed is 60 mph. The new vehicle features four-wheel suspension, adjustable-height platform, four-wheel drive, selective two or four-wheel steering, removable windshield and cab enclosure, and dual headlights.

Increased Mileage Claimed with New Carburetion

PHILADELPHIA—A method of cutting down gas consumption in Detroit's 300-hp cars was described at a recent ASME meeting by L. S. Conta and P. Durbetaki of the University of Rochester.

The major disadvantage of the spark-ignition engine that powers present-day autos is that it runs efficiently only at rarely-used top speeds.

In the new system, called "charge stratification," fuel is forced into the combustion chamber at a point very near the spark plug. The rest of the chamber is filled with a lean mixture. Special design of the chamber insures quick mixing of the burning charge with the lean gas.

Preliminary tests show that the equipment delivers high gasoline economy and also cuts pumping losses because it eliminates some tubing. Fuel ratios as high as 42 parts air to 1 part fuel, compared to a normal 15 to 1 ratio, have been achieved without engine knock.

Major obstacle to the use of the system on American cars has been lack of suitable fuel-injection equipment to spray the fuel into the combustion chamber. This type of equipment is said to be under development, and will make commercial adoption of such an engine relatively simple and inexpensive.

Please direct inquiries to advertiser, mentioning MACHINE DESIGN→

...Fluid Power news

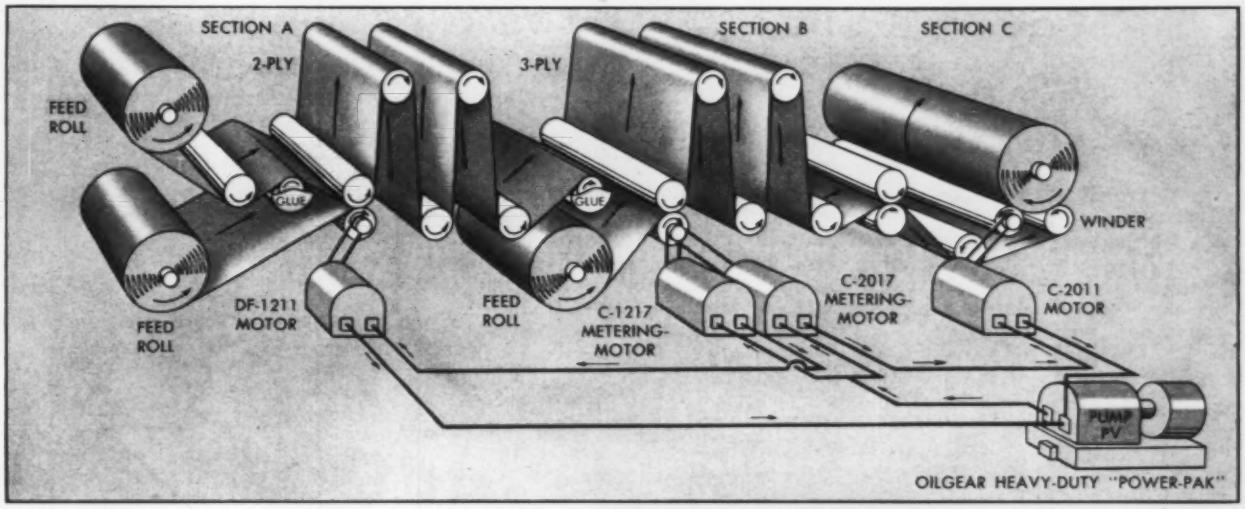
REPORT NO. 12,101
FAST-ACTING MULTI-STAGE DRIVE

From Oilgear Application-Engineering Files

HOW OILGEAR "*ANY-SPEED*" DRIVES SIMPLIFIED MODERNIZATION OF A LAMINATOR

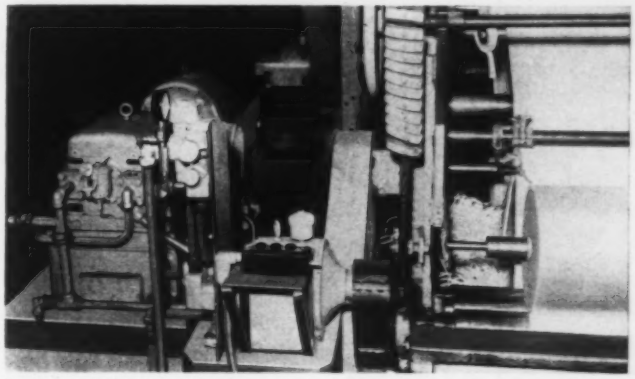
CUSTOMER: *A Large Midwestern Paper Manufacturer*

DATA: This company initiated an extensive equipment modernization program to enable expansion in competitive fields, and increase production efficiency. Part of this program consisted of adding a new section to an Oilgear-powered laminator and winder. *Requirements:* 1: Maintain proportional synchronization and power coordination between existing section and winder with new section. 2: Fast-acting controls for individual, precision, sectional speed adjustments. 3: Start, stop, change speeds rapidly, and run at *any* selected speed to maximum without tearing paper web. 4: Accurate, adjustable, automatic winder tension control. 5: Complete conversion in minimum of machine "downtime." 6: Selected drive must be thrifty on floor space and electrical power.



SOLUTION: Shown above schematically with new section A to left. Oilgear Heavy-Duty, *"Any-Speed"* drives were selected for this application primarily because of space savings, ease and speed of conversion, and long experience with Oilgear's *low-cost-per-year* operational record in their plants. Unusual application feature is the use of a single, Oilgear Size 35 "Power-Pak" as the Fluid Power source for all three exactly coordinated sections of this multi-stage machine. *Performance has proved superior to requested specifications — with no reported maintenance after more than two years of continuous, high-speed service.*

OPERATION: Oilgear type "DE" Variable Displacement Pump (PV) — accurately, remote pushbutton station controlled from zero to maximum output — drives two Oilgear type "C" fixed stroke, constant torque, radial piston motors (C-1217, C-2017). Acting as tandem motors, they power section B. They also act as meters for motors (DF-1211, C-2011) connected in series with them. Oilgear type "DF" variable stroke, constant hp, radial piston motor (DF-1211) powers new section A in series with section B motor (C-1217). Oilgear type "C" motor (C-2011) powers section C in series with section B motor (C-2017). Speed changes initiated from control station pushbuttons to Pump (PV), are imparted to section B, and proportionally to sections A and C. Proportional speed relationship between sections A and B is easily altered by stroke adjustment of motor (DF-1211). Speed relationship between sections B and C is automatically altered as roll diameter increases by an automatic winder tension valve. Maximum torque in section A is independently adjustable. Solenoid-operated brake valves insure rapid, cushioned stops. Rapid, cushioned starts are an inherent feature of Oilgear *"Any-Speed"* drives. This completely sealed, compact, fully pressure lubricated, *"Controlled-Motion System* delivers full rated torque at *"Any-Speed"* . . . automatically conserves electric power . . . quiet, vibration and trouble-free.



View from winder end of laminating machine after a "rush" conversion, completed and running without trouble ahead of schedule. Oilgear Heavy-Duty, Size 35 "Power-Pak" can be seen in left foreground. One pushbutton control station and winder tension valve are to left and in front of series driven, Oilgear type "C" motor which powers the winder section. Oilgear "C-2017" motor, one of the tandem drive metering-motors on the center section, can be seen in center background.

Because of Oilgear's long reputation for cooperative teamwork in solving drive problems with dependable, trouble-free Fluid Power Systems for virtually any application — Oilgear has become a name that all industry trusts . . . and uses.

For similar practical solutions to YOUR linear or rotary Controlled-Motion problems, call the factory-trained Oilgear Application-Engineer in your vicinity. Or write, stating your specific requirements, directly to . . .

THE OILGEAR COMPANY

Application-Engineered Controlled Motion Systems

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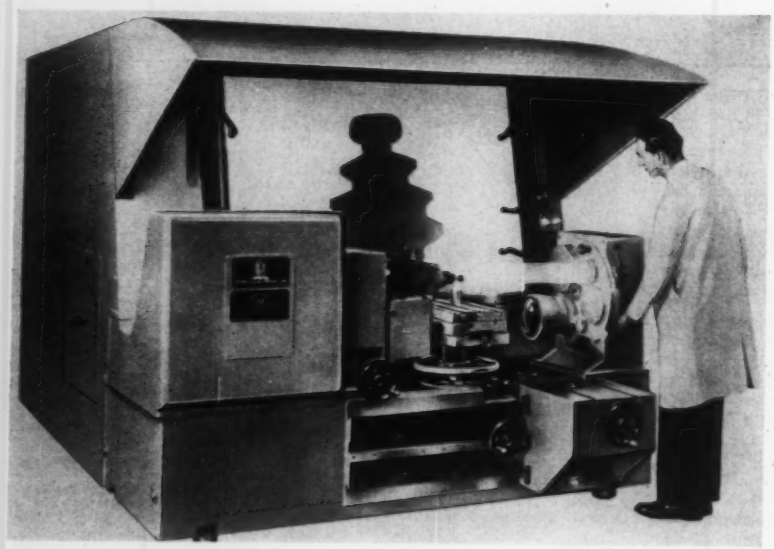
LETHAL-LOOKING stud driver rapidly attaches explosive charges on steel, wood, or concrete surfaces. The powder-actuated gun, developed by the Army Engineer Laboratories and the Ramset Div. of Olin Industries Inc., is a repeater type enabling the operator to make ten separate fastenings without reloading. Stud driver is designed primarily for demolition missions. Shown here are the gun, cartridge and stud, a loaded and unloaded magazine, washers to prevent studs from completely penetrating plates, special wrenches for assembling and disassembling the gun, and a cord with snap-fastener which attaches to the gun handle.



WIDE-SCREEN LOOK in optical gaging is provided by this big clear-screen projector, imported from England. It's designed for inspecting contours such as templates, gears, cam forms, and screw threads, and for visual finishing of profile gages. Screen is 60 in. wide and 40 in. high which permits inspection of parts covering a field of 6 in. at a magnification of 10x. Projector was developed by Optical Measuring Tools Ltd.; is licensed for U. S. manufacture by Optical Gaging Products, Rochester, N. Y.

Topics

Mechanical Paul Bunyan, able to go through a woods, fell trees, and pile them up, is sought by the newsprint industry. Planning of such a machine has been undertaken by a group of engineers, according to the Newsprint Information Committee, for the purpose of reducing the cost of getting trees to paper mills.

• • •

Three-and-one-half-inch-screen TV is back—in a set built for doll houses. The set is 6 in. high, 4 in. wide, and 2½ in. deep, and is housed in a console-type cabinet offered in mahogany, walnut, blonde, or cherry wood. The price—$350—includes the usual guarantee.

• • •

Ham and satellites can form an interesting and useful combination. A new booklet describes how the radio amateur, with minor modifications to his equipment, can receive and record information about meteors, cosmic rays, space dust and other phenomena in space. Such recordings may supply important data, since official receiving stations are in contact with each satellite for only a small part of its orbit. The booklet, "You Can Record the Satellites," deals with adapting basic equipment, recording information and interpreting data, timing recordings, and instructions for determining the value of data collected. Copies are available free at Audiotape dealers or from Audio Devices, 444 Madison Ave., New York, N. Y., for a 10-cent handling charge.

• • •

Well stacked automobiles more than double a ship's capacity. The British freighter *Lynton*, with crated Austins, Fords, Vauxhalls, etc., stacked four deep, now carries 710 cars, compared to the normal load of 300. Collapsible crates are returned for re-use. Four men can crate or uncrate a car in about 10 minutes.

• • •

In the red, in duplicate, is possible with a new carbon paper designed especially for accounting operations. The British-made carbon sheet has two vertical red strips which permit entering "red-ink" columns on two or more typed copies simultaneously.

• • •

Sunshine at picnics, always welcome, is especially desirable when the food is to be prepared on a new solar-powered broiler. The Umbroiler, which folds up like an umbrella, unfolds in the shape of a parabolic sun-mirror that catches the sun's rays and focuses them on the piece de resistance on the attached grill. The mirror of the Umbroiler is made of aluminized Mylar.

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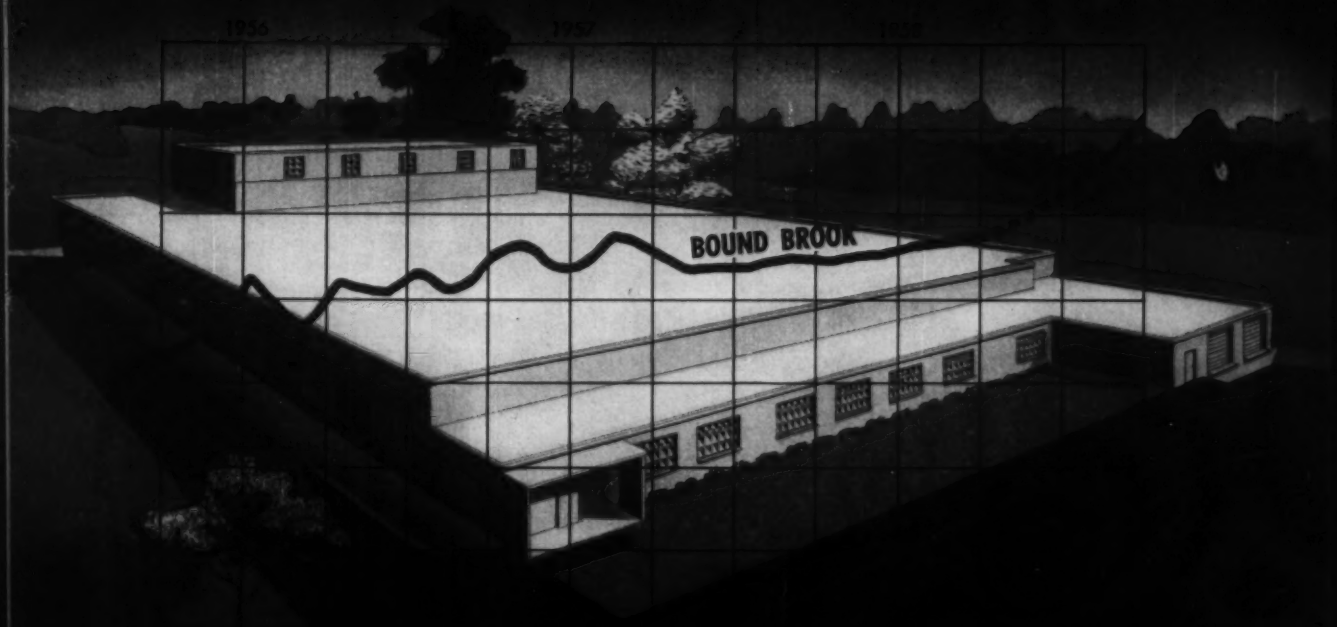
NEWS ITEM No. 4 – 1958 – NEW PLANT IN STURGIS, MICHIGAN



WHY EXPAND?

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2. CONFIDENCE IN OUR COUNTRY
3. CONFIDENCE IN BOUND BROOK'S ABILITY TO GIVE THE FINEST SERVICE IN THE FIELD OF POWDER METALLURGY

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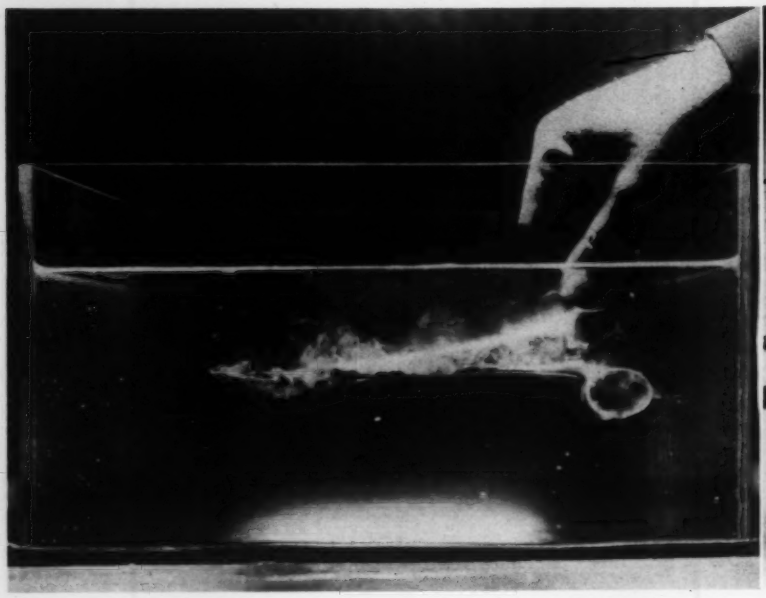
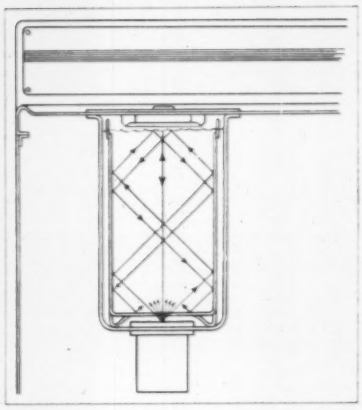


DRIED BLOOD and other foreign materials float off this surgical instrument immersed in tank of ultrasonically agitated water. Transparent working model was demonstrated to introduce ultrasonic washing machine, manufactured by Acoustica Associates Inc., Mineola, N. Y. The sound waves cause cavitation, or "cold boiling," of the liquid, resulting in the formation and collapse of tiny bubbles thousands of times per second. Bubbles provide the penetrating action which loosens, then disintegrates dirt and contaminants from the instrument's tiniest crevices and serrations. Nurse (above right) prepares to insert basket loaded with soiled surgical instruments into the washing machine. The washer reportedly cuts cleaning time and labor more than 80 per cent below conventional hand-scrubbing methods. The tank fills with water when attendant turns starter dial. The rest is automatic. When the cleaning cycle is completed, spray and fill-rinse cycle begins. Unit turns off, signaling that next basket may be processed at once.



SILENT SOUND waves radiate and reflect through water in deep-well tank. Ultrasonic waves radiate from transducer at bottom of tank to form a reflection pattern which provides all-around cleaning action.

Says Engineer Faces Problem: Product Must Cost Less

Executive Sees Major Role For Engineer in Economy

PITTSBURGH—Sharing technological gains with the consumer in the form of lower prices poses a major problem for today's engineer, said a noted executive recently. According to John K. Hodnette, executive vice president of Westinghouse Electric Corp., engineers must play a major role in solving the problem which has resulted in higher wages and prices, while employment, sales, and profits are down.

The rapid upturn in productivity, he said, began immediately after the Korean campaign. Since that time, the nation has raised its manufacturing capacity more than 50 per cent. "Today, as a result of this massive effort, we have a vastly expanded production capacity in almost every industry and for virtually every product and service," he stated. "Our economy is now faced with the problem of adjusting to these large additions to productive capacity."

He explained that in the past, "we have turned out greater and greater amounts of vastly improved low-cost commodities and services. And, we have created the American mass market to absorb this increased production. Today, however, something new has been added," he said. "We seem to be operating on the new principle that the benefits of productivity gains shall be. . . converted into increased wages without consideration of the other contributing factors. We are not properly reflecting the contribution of engineering, advanced mechanization, or the investment required for these gains.

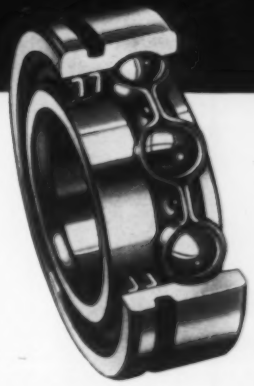
"This situation has also produced the strange imbalances we see in our economy today. Wages and prices have been hitting new high points at a time when employment, sales, and profits have been dropping. This is contrary to the law of supply and demand, and it obviously cannot continue for very long." Although much of the problem must be solved by industrial management, the Westinghouse executive challenged engineers "to provide a very large share of the total solution" and said they would be expected to perfect still more efficient machines and production

ND FACTS

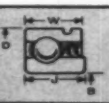
LUBRICATED-FOR-LIFE DISC BEARINGS CUT MAINTENANCE ON PLOWS

Disc plows mounted with New Departure integrally sealed, factory-lubricated ball bearings require NO field servicing. In fact, no grease fitting is provided or even needed. With New Departure ball bearings, discs turn freely, wear evenly and longer. They remain fully adjusted . . . assuring no unplowed furrows. And . . . with field adjustment eliminated, there's never a danger of bearing contamination.

Photo: Courtesy of J. I. Case Co.

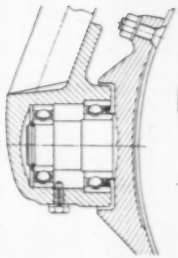


DIMENSIONS

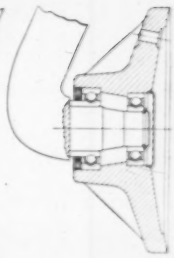
TYPE I  TYPE II TYPE III

Plow Size*	Position	Bearing Number	Type	Bore B	Diameter D	Width W	Width J
24 RS	Front	905422	I	1.6250	3.2677	1.014	1.024
24 RS	Rear	3207	III	1.3780	2.8346	.669	—
24 SS	Front	3208	III	1.5748	3.1496	.709	—
24 SS	Rear	905422	I	1.6250	3.2677	1.014	1.024
28 RS	Front	4510 A	II	1.9685	3.5433	.787	1.297
28 RS	Rear	3208	III	1.5748	3.1496	.709	—
28 SS	Front	3208	III	1.5748	3.1496	.709	—
28 SS	Rear	4510 A	II	1.9685	3.5433	.787	1.297
32 RS	Front	3L13	III	2.5591	3.9370	.709	—
32 RS	Rear	3210	III	1.9685	3.5433	.787	—
32 SS	Front	3210	III	1.9685	3.5433	.787	—
32 SS	Rear	3L14	III	2.7559	4.3307	.787	—

*RS indicates rotating spindle; SS indicates stationary spindle



Rotating spindle disc plow mounting featuring a two lip integral seal bearing.



Stationary spindle disc plow mounting featuring extended inner race for mounting external seal.

SEND FOR CATALOG FIC-B

1908–1958 GM FORWARD FROM FIFTY

NEW DEPARTURE

DIVISION OF GENERAL MOTORS, BRISTOL, CONN.

NOTHING ROLLS LIKE A BALL

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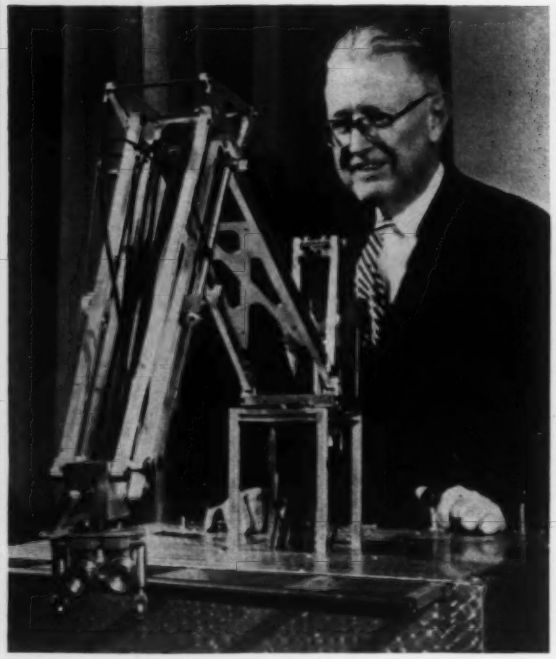
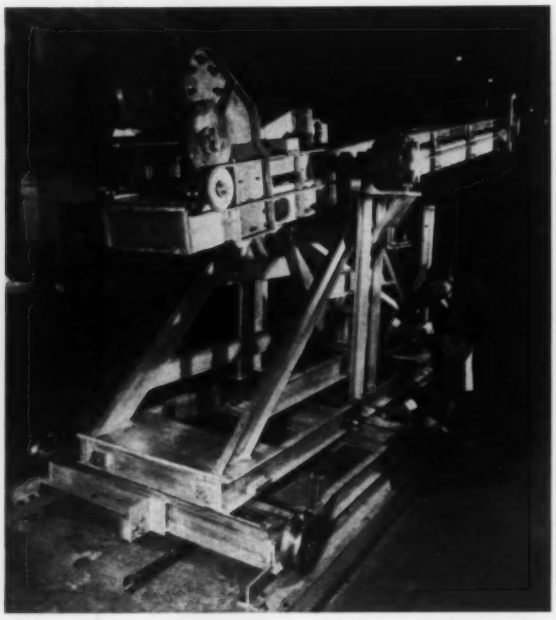


AUTOMATIC HOSE BOOM, for conveying oil hose from dockside to ship's manifold, assures faster "turn around" for tankers. Present methods of connecting oil hose require 8 to 10 men and take from 1 to 2 hr. With the new rig, one man can steer two 12-in. hose lines directly to the manifold in 3 min. During operation, hose is kept horizontal to ship regardless of change in ship's elevation from tide and loading. Developed by U. S. Rubber Co., the unit operates hydraulically; can be modified for air or electricity.

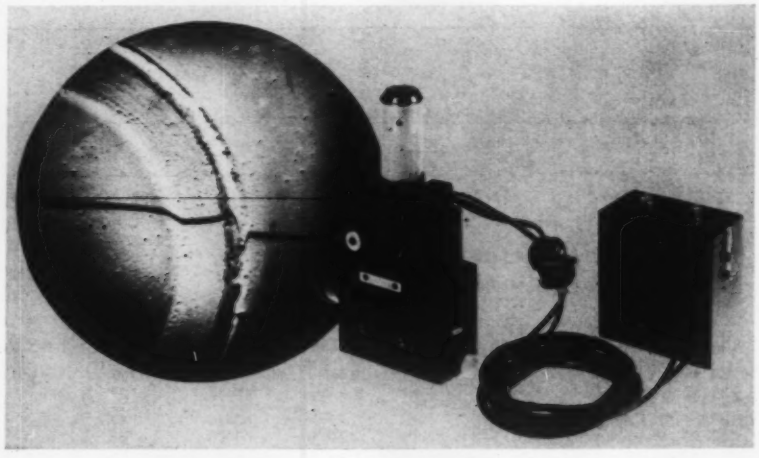


MACHINE UNDER WATER will handle radioactive materials. Running on a small railroad track, it will be capable of operating at all times under 18 ft of water which is used as protective shielding. Requirements for the safe handling and transportation of large radioactive samples led to its design. Known as a Thimble-Loading Machine, the device was built for Westinghouse by the Mechanical Div. of General Mills Inc. of Minneapolis. It has been designed to handle experimental containers, or thimbles, 18 ft long and $2\frac{1}{2}$ in. diam; moves them about 100 ft.

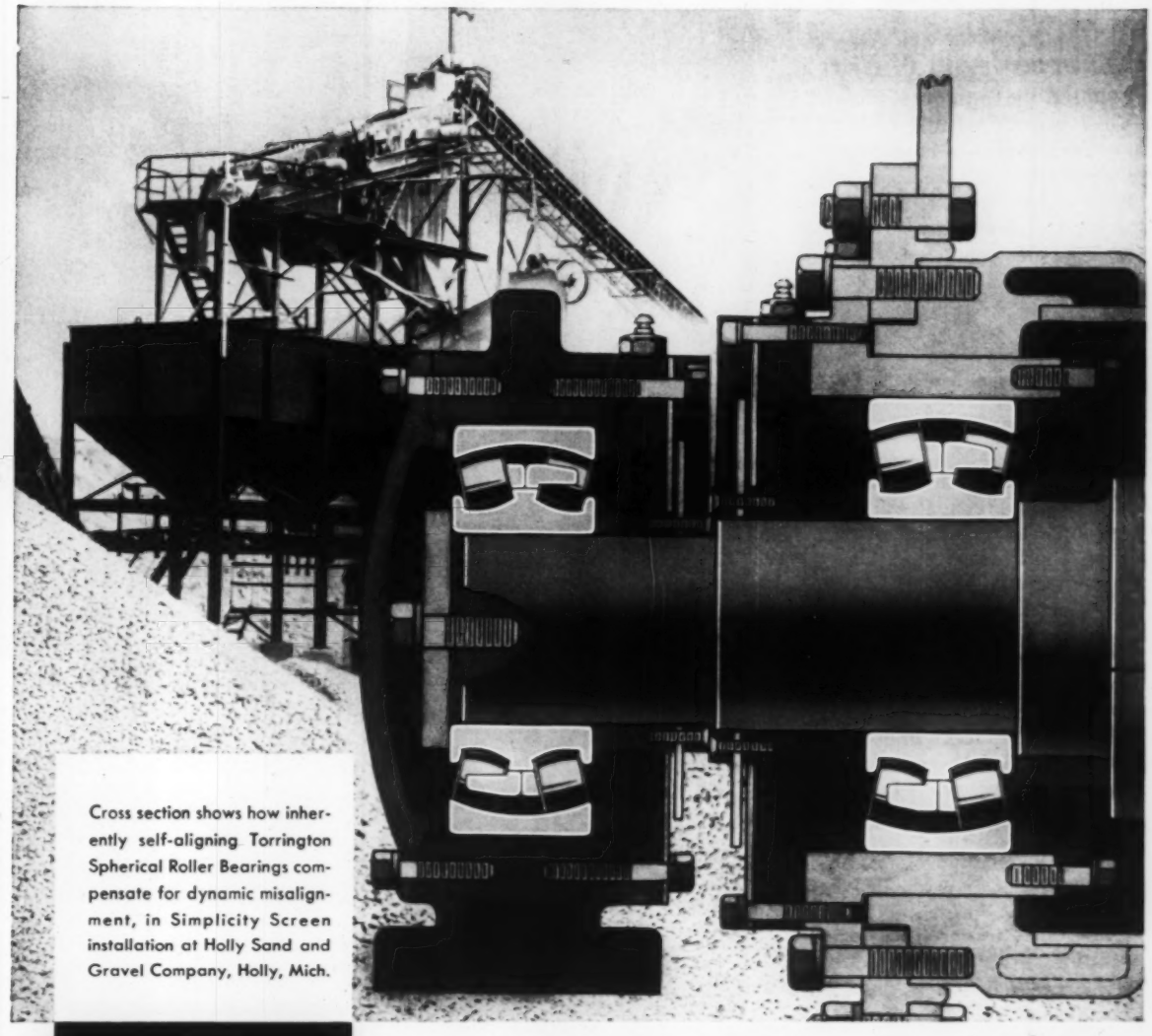
methods.

"Management must now, as never before, use improved machines and fresh methods to bring unit production costs still lower," Hodnette said. "It must struggle to translate these lower costs into lower prices. If it can do this, sales volume will rise and production lines stabilize."

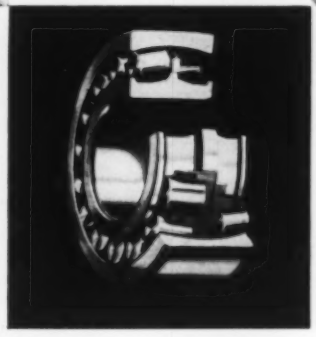
As an example of the need for improved machining operations, Hodnette cited the coal industry. In 1936, coal was being produced at the rate of 4.4 tons per man-day, and less than 20 per cent of this was mechanically loaded. Today with a shortened man-day, that rate has climbed to more than 8.5 tons and the continuous mining machine "is the rule rather than the exception." Looking ahead, Hodnette predicted consumption 6 to 8 times the present rate. To achieve such increases at low costs, he said, in the face of more difficult mining conditions—will certainly be one of the major engineering challenges in the coming decades.



SCRATCH-DEPTH INDICATOR employs principle used by astronomers for measuring the depth of moon craters. A light ray strikes the bottom of the scratch or pit mark at a known angle and the length of the shadow is automatically measured by the instrument. The indicator, developed by Boeing Airplane Co., Seattle, Wash., has a set of lenses with 36X magnification. Calibrations on a simple adjustment knob give depth measurements to 0.0001 in. The "part" to the left is a scratched skin surface enlarged to match the magnifying power of the instrument. Besides scratches and pits, the instrument can measure the thickness of paint and the flushness of abutting surfaces of metallic sheet and tube.



Cross section shows how inherently self-aligning Torrington Spherical Roller Bearings compensate for dynamic misalignment, in Simplicity Screen installation at Holly Sand and Gravel Company, Holly, Mich.



TORRINGTON

Spherical Roller Bearings Roll Freely Under Shock and Eccentric Loads

Inherently self-aligning, Torrington Spherical Roller Bearings roll freely at full capacity despite deflection of equipment framing or shafts under load.

This feature contributes to smooth operation and long life in Simplicity Engineering Company Screens. Positive roller guidance by the integral center flange provides constant and uniform roller contact with the race under radial and thrust loads, reducing wear and friction under shock and eccentric loading conditions.

Construction equipment of all types benefits from the advanced design features of Torrington Spherical Roller Bearings. To secure unsurpassed performance with minimum maintenance, specify Torrington. **The Torrington Company, South Bend 21, Ind.—and Torrington, Conn.**

TORRINGTON BEARINGS

District Offices and Distributors in Principal Cities of United States and Canada

SPHERICAL ROLLER • TAPERED ROLLER • CYLINDRICAL ROLLER • NEEDLE • BALL • NEEDLE ROLLERS • THRUST

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Ten Commandments Of Ethics Proposed By Engineers' Council

SAN FRANCISCO — "High-sounding phraseology and idealistic statements are not sufficient in defining conduct for engineers when it comes to professional ethics." So spoke the newly-elected President of Consulting Engineers Council, Charles C. Pate, as he addressed the Council's Second Annual Board of Directors meeting in San Francisco.

"A detailed code, written in plain English, and as easily understood as the Ten Commandments," was proposed by President Pate as an answer to this need.

The Committee recommended the following statement of policy, which was adopted by the Board.

"A Consulting Engineer shall not share fees except with other registered professional engineers or registered architects. In no case shall so-called split fees, finder's fees, commissions, kickbacks, or other benefits be condoned. It is to be understood, however, that interprofessional practice (for example, with architects), on the basis of any recognized ethical contractual basis, is approved. Furthermore, in soliciting work, a Consulting Engineer shall be represented only by those individuals regularly employed by, or known to be associated with, his office."

The Council also adopted a resolution regarding procedure for answering bid requests for engineering services.

"It shall be considered unethical practice for any member of the Consulting Engineers Council to submit a quotation for engineering services which is solicited by mail, or in any event where he has reason to believe that other engineers are being requested to submit a quotation for the same services.

"Elements considered to constitute a quotation include: Total fee, fixed fee, percentage fee (other than by reference to an established and recognized fee schedule), man-hours, hourly rates, or any combination of such elements. Replies to such solicitations shall be limited to listing technical qualifications and availability."

SCIENCE AND ENGINEERING are depicted by two 10-ft high murals, which flank entrance to new Brooklyn Polytechnic Institute building. Panels are the work of noted muralist Abraham J. Tobias. They represent new technique in murals, based on the passage of light through multiple colors and layers of Plexiglas. The relative color values of the murals remain constant whether seen under transmitted or reflected light.

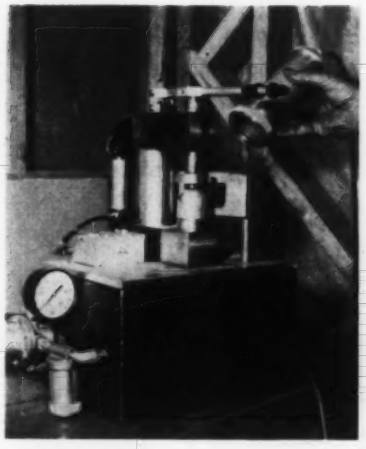
Electronic Chauffeurs Fail To Match Human Drivers

Automatic Cars and Roads Await New Techniques

NEW YORK—Although human drivers are relatively unreliable, electronic devices presently available for automatic car control are much more fallible, according to J. B. Bidwell of GM's Research Staff.

His comments were based on tests with two GM experimental vehicles, a Unicontrol car that is steered, accelerated, and braked by a single stick control, and a car that is steered automatically by a magnetic path produced by a cable in the pavement (MACHINE DESIGN, Mar. 20, 1958).

According to Bidwell, statistics indicate that about 96 per cent of fatal and nonfatal auto accidents result from driver error. However, National Safety Council records show that only one accident fatality occurs for each 16 million miles of vehicle travel, or approximately



MAGNETIC GAGE locates curved steel barriers in shaped explosive charges. Developed by Stanford Research Institute's Poulter Laboratories, the concentricity gage accurately locates a solidly encased component when it is not visible to the eye, and detection by other means is unsafe or impractical. Main unit is shown with dummy charge in operating position.

every 400,000 hr.

If failure of an automatic control system might be expected to cause one fatality, system failures must not occur more frequently than once per 16 million miles or 400,000 hr to maintain a safety record as good as at present.

Statistics thus give today's electronic chauffeur a subhuman rating from a safety standpoint, but improvements in electronic techniques and component developments undoubtedly will strengthen its future reliability.

Automatic control of urban traffic poses the most difficult driving problems, Bidwell said. "Cars would need very complicated decision-making equipment for completely automatic control. The most feasible initial application of automatic control is on limited access highways which might handle both manually and automatically controlled cars.

"If such a system is practical," he said, "motorists could lease equipment for trips on automatic highways and it would be unnecessary for all vehicles to carry complete equipment which could be used only a relatively small fraction of the vehicle's operating time."

DRAFTING TRENDS

At Universal Oil Products Company, Chief Draftsman M. F. Perkins checks the working qualities of Post pencil cloth with Joe Mania of the Drafting Division.

More drafting rooms use pencil cloth for ink-like lines at pencil speed

We've noticed that more and more drafting rooms are using pencil cloth for important originals. (We're particularly interested because Post was the first U. S. manufacturer of pencil cloth.)

While cloth is naturally more expensive, many draftsmen feel that the cost is nominal compared with the expensive time and effort that goes into an original drawing. They feel that paying a little more for the *durability* of cloth is a common-sense investment.

For speed and ease of working, pencil cloth is probably the best medium of all. Many draftsmen use it for drawing, primarily because of its easy working matte surface and good erasability. At pencil speed, it gives a jet black line with density approaching ink. Reproduction from pencil cloth is consequently very good—sharp and precise with excellent contrast.

Two good examples of recent improvements in pencil cloth are Post's *Whitex* and *Penciltex* (blue tint). Both are available in either regular or smooth surfaces for different degrees of pencil hardness. The texture is precisely formulated for dense, opaque lines at high drawing speeds. All are moisture-resistant and highly transparent.

The most popular feature of *Whitex* and *Penciltex* is the unusual erasability. Even 6H pencil lines erase without "ghosting". Just as important, they hold up well after working and reworking in one place. Our researchers are constantly testing different tracing cloths and they tell us that *Whitex* and *Penciltex* have the finest erasing qualities of all leading cloths.

Eradicating unwanted elements

For users of Post pencil cloths, an extremely simple and satisfactory method of eradicating is the use of Post Liquidator.

Applied on Post cloths, Liquidator saves time and labor in erasing large areas. More important, it permits repeated redrawing "good as new" over eradicated areas without change of pencil degrees. This assures uniformity.

For further information on these Post products see your Post dealer or write today to the Readers Service Division of Frederick Post Company, 3652 N. Avondale Avenue, Chicago 18, Illinois.

POST

SENSITIZED PAPERS & CLOTHS • TRACING & DRAWING MEDIUMS • DRAWING INSTRUMENTS & SLIDE RULES
ENGINEERING EQUIPMENT & DRAFTING SUPPLIES • FIELD EQUIPMENT & DRAFTING FURNITURE

Friendly inferno— to make BETTER GEARS

THIS 100% forced convection furnace is just one unit of the highly specialized equipment used in making "Double Diamond" gears. Because we manufacture gears—and only gears—we avail ourselves of every kind of improved technique and equipment that will produce completely controlled quality.

What does this mean to you? Simply this:

BETTER GEARS that offer the advantages of lower installed cost, economical and dependable service on the job for which you buy them . . . gears that do credit to your product and your reputation.

Our gear engineers are available for consultation. Just write.

In this controlled atmosphere furnace, 100% forced convection heating of gears by Automotive Gear Division insures uniform heating of every part to the desired temperature. Through the entire operation—pre-heating, carburizing, hardening and modified Marquenching or regular quenching in selected grades of oil—time, temperature and atmosphere in each zone are automatically controlled. Thus, the quality that is cut into the gear is retained.

EATON

AUTOMOTIVE GEAR DIVISION
MANUFACTURING COMPANY
RICHMOND, INDIANA

GEARS FOR AUTOMOTIVE, FARM EQUIPMENT AND GENERAL INDUSTRIAL APPLICATIONS
GEAR-MAKERS TO LEADING MANUFACTURERS

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Reader Information Service

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EDITORIAL CLIPSHEETS—So you won't have to "clip" this issue, we'll be glad to send a personal copy of any article as long as the supply lasts. Just fill in the page number and title of article in the place provided on the Yellow Card.

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May 29, 1958

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403	428	453	478	503	528	553	578	603	628	653	678	703	728	753
404	429	454	479	504	529	554	579	604	629	654	679	704	729	754
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422	447	472	497	522	547	572	597	622	647	672	697	722	747	772
423	448	473	498	523	548	573	598	623	648	673	698	723	748	773
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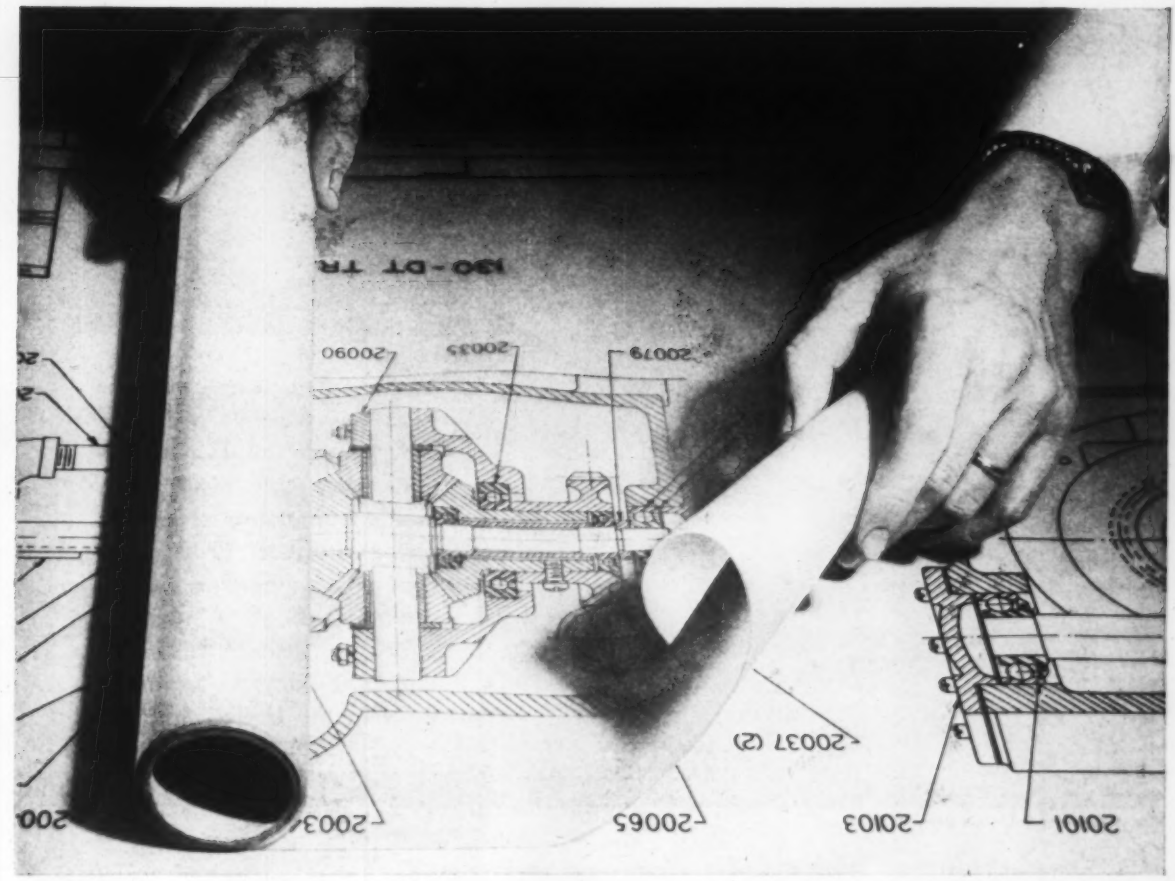

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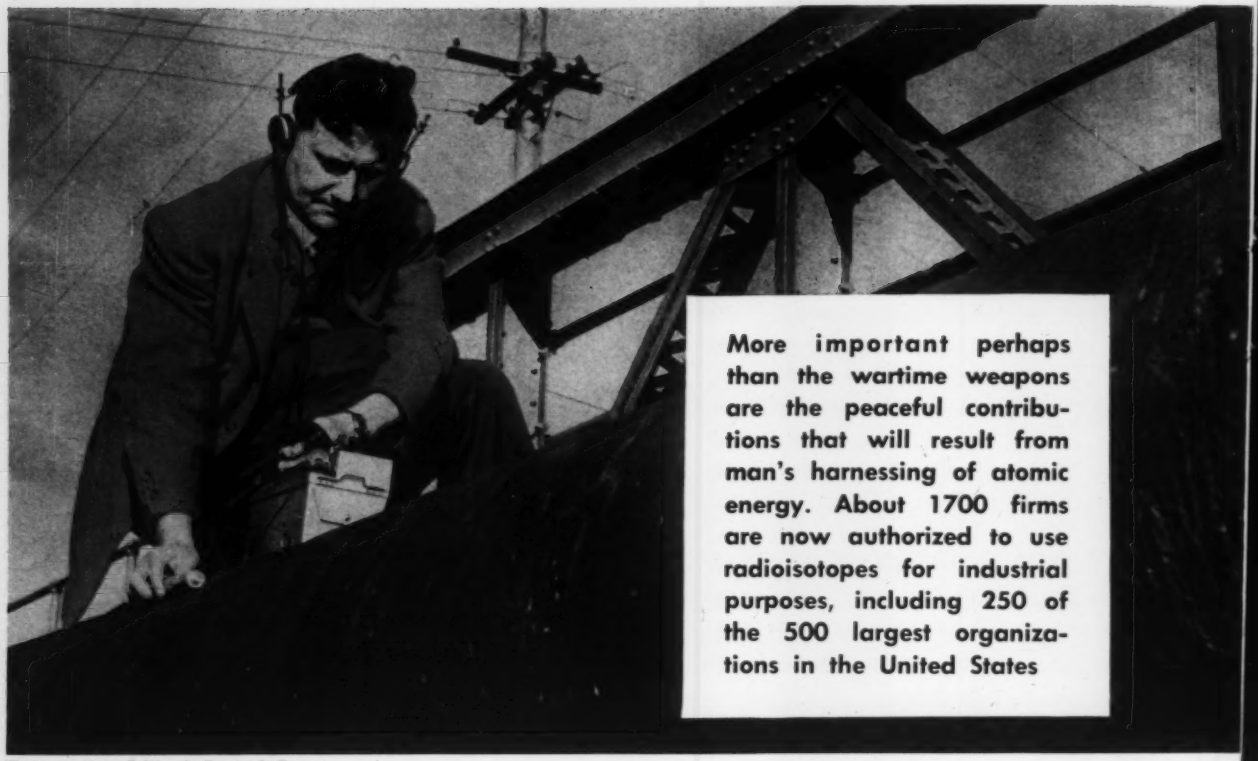


More important perhaps than the wartime weapons are the peaceful contributions that will result from man's harnessing of atomic energy. About 1700 firms are now authorized to use radioisotopes for industrial purposes, including 250 of the 500 largest organizations in the United States

Photo, courtesy California Research Corp.

What's a Radioisotope?

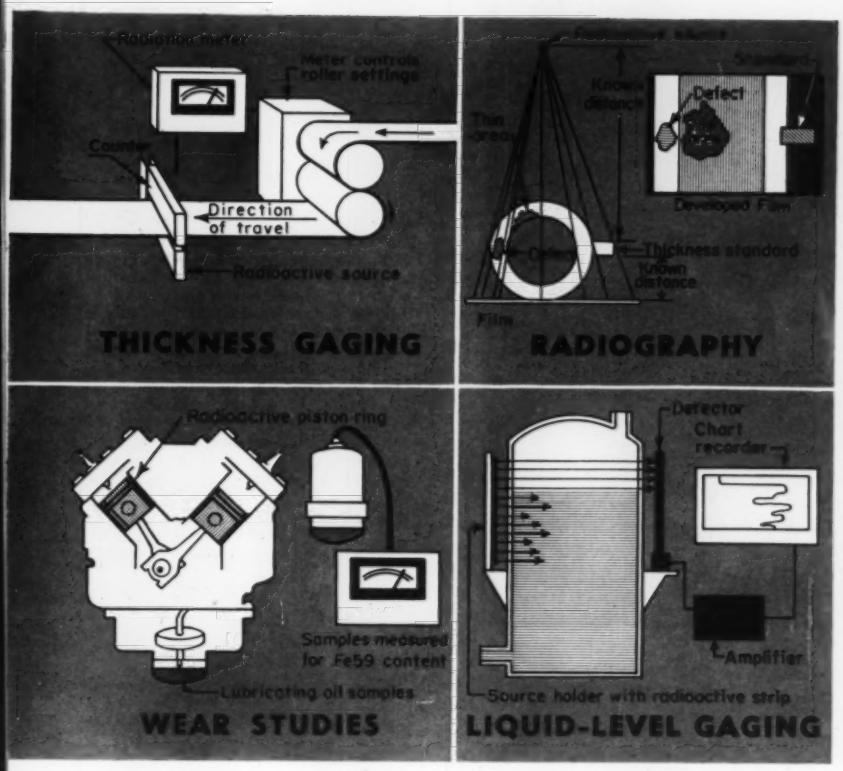
A radioisotope, defined simply, is one of a number of unstable chemical elements. As each of its atoms seeks a more stable energy state, it emits energy. The principal radiations from radioisotopes are alpha particles, beta particles, and gamma rays. Alpha particles are positively charged helium atoms, beta particles are electrons, and gamma rays are similar in nature to x-rays and light waves.

Some radioisotopes such as radium and uranium occur in nature; others—for example, cobalt 60 and strontium 90—are man-made byproducts of nuclear reactions. Each radioisotope has its own characteristic type and energy of radiation, which together with cost considerations, determine its merit for a given application.

Although many uses of radioisotopes are not new, the full force of their benefits is yet to be realized. Only in recent years have they become widely available at low cost to industry. The radioisotope offers these capabilities: penetration of radiation, reflection of radiation, luminescence, ionization, stimulation of chemical reactions, voltage production, and tracing.

Long under study in the laboratory, radioisotopes are only now entering industry where their uses are being expanded and are being designed into new products, still in their infancy. A full appreciation of the atom still awaits even more diverse applications in process-control and new-product design, and later, widespread trials in actual service.

A TINY experimental battery powers a wrist watch. The battery is smaller than a dime, has a useful life of more than five years, and delivers 20 mu w of power. Although it is not yet available for everyday use, larger future models of the battery are expected to power portable radios, hearing aids, and equipment in guided missiles and



Thickness gaging is one application of the radiation penetration principle. This continuous method of gaging is nondestructive, does not involve contact with the material, and is especially useful where products are moving rapidly. The material whose thickness is to be gaged is passed between a source of radiation and a detector connected to an amplifier and a recording device. Often, the signal caused by the radiation transmitted through the material is used to make automatic corrections in production.

Radiography with radium or x-rays is a comparatively old method for inspecting metal castings and welds for possible flaws not detectable except with the radiation and film technique. Reactor-produced cobalt 60, cesium 137, and iridium 192 now are used in much the same way as radium, but are much cheaper and more effective. More than 550 firms are licensed to perform radiography with radioisotopes.

Radioactive iron is used for friction and lubrication studies. This technique permits measuring transfer of metal to 0.00001 oz. Oil is sampled during operation of the motor. Film studies show location of wear.

Measuring liquid levels is another application of the radiation penetration principle. Any drop in liquid level exposes more radiation. The liquid-level gage permits continuous measurement and accurate recording without contact.

ATOMS in industry

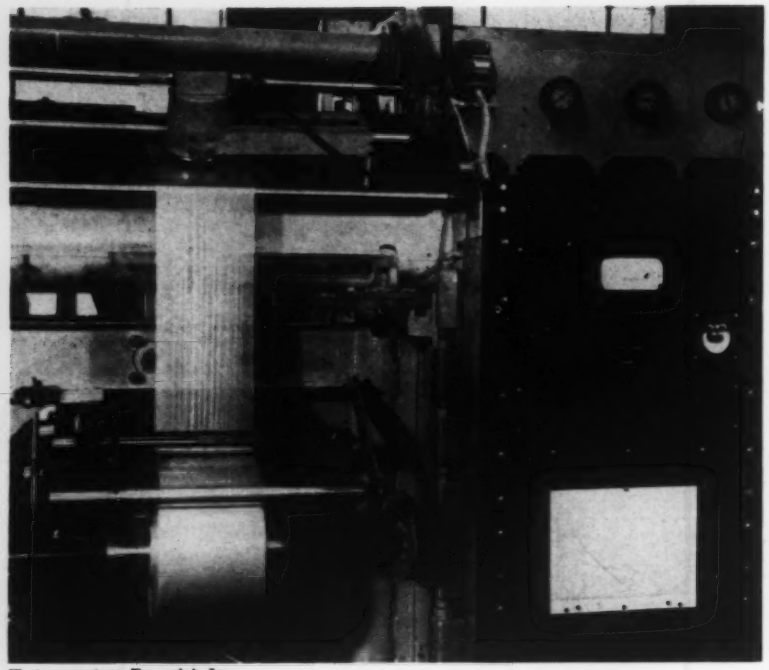
Use of Radioisotopes Grows

space craft. It uses the radioisotope, promethium 147.

"Heatless vulcanization," the first basic change in the curing of rubber since the discovery of vulcanization in 1839, produces tires which wear longer and resist deterioration better than tires vulcanized by the conventional method of heating to more than 300 F. The new process uses radiation from atomic energy byproducts.

A military tank manufacturer experienced failure with the mount supporting the large gun. Failure of the mount permitted the heavy gun to recoil into the tank, causing severe damage and endangering the occupants. Gunmounts were thereafter radiographed as a matter of routine. The radiographic check revealed that several had internal flaws not detectable by other means. This virtually ended the failures. Because the mount's configuration prohibited the use of any conventional form of radiography, only radioisotopes of high specific activity could be used.

Radioisotopes find use in indus-



Photo, courtesy Tracerlab Inc.

Gages are most widely accepted of all radiation devices. Here, beta gage measures weight per unit area of plastic as it comes through manufacturing process. The amount of radiation picked up by the detector depends upon the amount of material between it and the radioactive source. Product thickness, or density, is measured by detecting the attenuation, or absorption, of the radiations from a source as the emissions pass through the material under observation. Such nuclear gages have taken many ingenious forms and thousands are in use.

try either because they result in cost savings or because they make possible what could not be done by other means. When industry wants to know what progress is being made in the use of radioisotopes, it usually turns to estimates of annual cost savings prepared by the Atomic Energy Commission.

In 1953, AEC estimates showed radioisotopes saving American industry about $100 million per year. A review in November, 1956, based on interviews with some of the industries using radioisotopes, indicated savings had increased to a probable value of $390 million annually. The most recent investigation, in July, 1957, indicated annual savings at $406 million, which would make current industrial annual savings an estimated $500 million. Dr. W. F. Libby, AEC commissioner, has predicted a tenfold increase within the next four or five years: savings by about 1962 amounting to $5 billion.

Oscar M. Bizzell of the AEC staff visited about 40 of the largest industrial firms either manufacturing or using radioisotope products and compiled supplementary information from 100 other organizations.

What's the present status of the radioisotope field?

According to Mr. Bizzell, "Many of the more aggressive firms have already entered the field, and others are now forced to enter in order to keep abreast of competitive developments. Some have hesitated because of what they considered the possible dangers of radiation. It's a new hazard to them—one that I thought was probably far less than many that they face on a day-to-day basis, and this is fairly rapidly being dispelled."

How can the design engineer learn more about radioistopes?

Thomas Kelley of Tracerlab Inc., Waltham, Mass.: "Too much has been written of very specific, very sophisticated applications. It doesn't help the engineer gain background information he can apply to his own problems. I think radiation uses are recognized, understood, and pretty readily handled by somebody who's familiar with them. It's not something, however, that a good many engineers who are outside the radiation field understand—so the problem becomes magnified out of proportion. Engineers who are familiar with the fundamentals of the art can easily see their way to many possible applications.

One of the keys to greater adoption of radioisotopes, says Mr. Kelley, is for engineers to learn to apply the various control practices. He cites a continuous increase in the number of users of thickness gages. More important than the reason for first trying a gage, he points out, is the industrial users' continued acceptance that this is the best way to do many jobs. As people become more familiar with gages, he says, they don't just use them with recorders or in other simple applications—they automate the whole process.

According to Kelley, "Radioisotopes in processing are very, very diversified in application. Almost anybody making any kind of sheet material or laminations or coatings or any such combination of material would be ill-advised not to consider using gages. We do find some places where they're just not suited, but we find more and more every day where they are suited."

Auto manufacturers have been among the first to adopt radiation techniques. In this "radioactive materials room" at Chrysler, many metals, better designs, smoother running, longer-lasting parts have their beginning. Work is being concentrated on an engine distributor point, which has been made radioactive in the pile at Oak Ridge, Tenn. Ford and General Motors are also among firms making extensive use of radioisotopes.

What control applications can help engineers?

Philip E. Ohmart of the Ohmart Corp. in Cincinnati: "Automation would not be possible in many industrial applications without having the radiation control instruments. We've applied beta radiation recently to separate fat content from meat intended for babies' consumption. Things of that type have not been done before. This ended up as a control device on an assembly line that automatically controls the centrifuge cycling operation. It has decreased the batching time and improved the product quality."

Radiation devices, according to Ohmart, that are more or less standard control devices, can be used to increase the efficiency of various products. He cites two examples. Dredging depth is controlled by regulating the height of sweeps on barges. A gage installed on the inlet pipe measures the per cent of solids coming in, and if the ratio of solids drops, the sweep is lowered. If solids go too high, the sweep is raised. Discussing pumps, he says, the pump designer will assign nominal ratings because the user normally has no control over incoming solids, and he doesn't want the customer to exceed the pump's capability. He can increase the rating, however, when the customer feeds a more constant product into the equipment, as he is able to do by installing suitable gages.

"On this," said Ohmart, "one of the primary things is getting a realization of the economics over to people. People starting to use radiation must learn that it is not the initial price of the equipment that is important; it is the payoff rate."

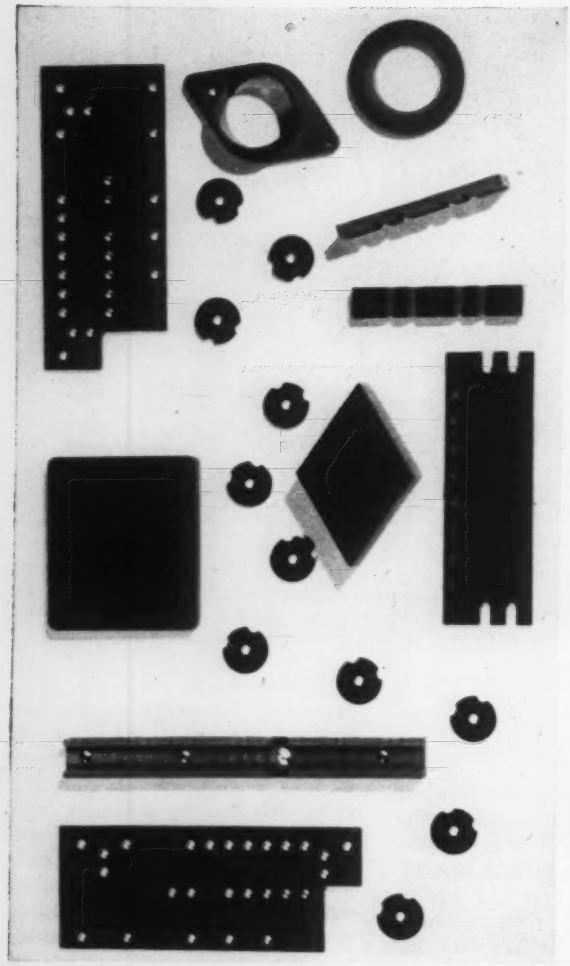
What's the future for radioisotopes?

George B. Foster of Industrial Nucleonics Corp. in Columbus, Ohio: "The growth in medium-term rewards to be gained from radioisotopes lies in extending their scope of applications rather than in new 'hot-rod' ideas. Radioisotopes have been almost universally adopted in some process industries, notably in the processing of resin-impregnated laminates, where almost all manufacturers have adopted radioisotope thickness gages. Mechanical laminates used for structural purposes, electrical laminates used for insulation and printed circuits, and decorative laminates, are all controlled in manufacture by thickness gages. Also, I would guess that well over one-half of all rolling mills make use of radioisotope methods in the manufacture of steel and tinplate."

"Many other industries, however, have had pilot installations for over five years," Foster says, "but the widespread adoption of radioisotope techniques has not followed. This has largely been a cost-accounting problem. Current accounting practices have not reflected the very substantial economic benefits from these installations which have accrued to their users. This situation represents a real challenge in communications and sales technique to manufacturers."

Typical of thickness gages are some 400 used in paper mills. These gages automatically adjust gates regulating the inflow of materials to maintain accurate basic weight and thickness of rolls of paper.

"The adoption of radioactive isotopes," according to Foster, "could have been faster." As he sees it, the problem has been in getting the message across. Future for the field, he says, can be summed up in the phrase, "You ain't seen nothing yet." —B. D. Ross



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	X-13 (NEMA X)	XP-13 (NEMA P)	XX-13 (NEMA XX)	XX-13 FR (Fire-retardant) (NEMA XX)	XXXP-28 (NEMA XXXP)
ROCKWELL HARDNESS	100	95	110	108	90
TENSILE STRENGTH lw (1000 psi.)	20	12	16	17	12
FLEXURAL STRENGTH lw (1000 psi.)	27	16	17	20	18
COMPRESSIVE STRENGTH (1000 psi.)	40	25	35	41	22
WATER ABSORPTION (% in 24 hrs.) 1/16" thickness	3.5	3.0	1.4	1.2	0.6
MAXIMUM CONTINUOUS OPERATING TEMPERATURE (°C.)	120	120	120	120	120
DIELECTRIC STRENGTH perp. to lam. (VPM)	800	800	650	700	800
DIELECTRIC STRENGTH parallel to lam. (Kv.)	50	50	60	70	75
DISSIPATION FACTOR at 1 mc, Cond. A	0.042	0.038	0.034	0.038	0.027
DIELECTRIC CONSTANT at 1 mc, Cond. A	5.5	4.6	4.7	4.8	3.6
ARC-RESISTANCE (seconds)	8	4	4	10	10
INSULATION RESISTANCE (megohms) ASTM D-257, Fig. 3	100	100	1,000	1,000	600,000
AIEE insulation class	A	A	A	A	A

Circle 413 on Page 19

Survey

Shatters Negative Image of

Scientist as a Person

COMBATING IMPRESSIONS of the scientist as a "square" or a hermit, a research executive recently told of a survey which reveals the typical American scientist to be a family man, interested in civic, social, and religious affairs.

He cited by contrast a poll of high-school students by Purdue University which found that 14 per cent thought there was something evil about scientists; 19 per cent said scientists are more likely to be mentally ill than other people; 20 per cent thought scientists have little regard for humanity; 34 per cent believed scientists cannot have a normal family life; and 38 per cent thought scientists willing to sacrifice the welfare of others to further their own interests.

"I feel very strongly," said Mr. Samuel Lenher, a vice president and formerly a chemist of the E. I. du Pont de Nemours and Co. of Wilmington, Del., "that the negative image, and the extent to which it discourages young people from scientific careers, is of very serious concern to all of us."

Cited also by Lenher was a study conducted by Drs. Margaret Mead and Rhoda Metraux for the American Association for the Advancement of Science, entitled "The Image of the Scientist Among High School Students." For this study, students in more than 120 high schools were asked to write essays on what they thought about science and scientists. Out of this came what the authors decribed as three images—the shared, the positive, and the negative. Drs. Mead and Metraux concluded that this image is likely to invoke a negative attitude as far as a personal career or a marriage choice is concerned. Mr. Lenher presented survey findings of 1200 Du Pont research men and reviewed, point by point, the high school students' negative image as compared with survey data:

1 **A scientist should not marry. No one wants to be such a scientist or to marry him.**

Eighty-eight per cent of the scientists surveyed are married, compared to 85 per cent of the general adult population. Seventy-three per cent of their wives attended college. The average number of children per family is slightly more than two, compared to one and one-half for the average American family.

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2 **His work may be dangerous. Chemicals may explode. He may be hurt by radiation or may die.**

The company, dealing with chemicals, operated the Hanford atomic materials plant during World War II, and now operates the Savannah River plant for the production of atomic materials. Injury frequency rate is one man in 3 million exposure hours as compared with the rate for all American industry of one man injured in 160,000 exposure hours.

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3 **He may not believe in God or may lose his religion.**

Although the survey did not inquire whether scientists were church members, about 75 per cent mentioned church in listing their activities. Fifty-seven per cent took active part in church affairs beyond membership or attendance, including Sunday School teaching or supervision, offices such as trustee or elder, membership in men's clubs and on committees, choir singing, and assisting youth groups.

SCIENTIST AS A PERSON

4

He is a brain; he is so involved in his work that he doesn't know what is going on in the world. He has no other interests and neglects his body for his mind . . . He has no social life, no other intellectual interest, no hobbies or relaxations.

The survey showed 37 per cent of the scientists participate in 64 different civic activities. Activities mentioned included membership in community councils or associations and in fund-raising groups. About one-third of the scientists participate in the work of Parent-Teacher Associations. Twenty-two surveyed were involved in district, state, or national PTA groups, while nine were members of Boards of Education. About one in five is active in Boy Scout work. Others are active in YMCA work. Twenty-one per cent are active in fraternal organizations.

When it comes to music, the scientists listed 54 different activities with 22 per cent participating in either vocal or instrumental groups both within and outside the company. Mr. Lenher interjected here a personal recollection of a lively Dixieland jazz band known as "The Rhythm Doctors" because its members were Ph.D.'s engaged in research.

Few of the scientists can be said to neglect their bodies for their minds. Seventy per cent of them engage actively in 42 different sports. Golf is the most popular, with bowling second. Tennis is third, followed by fishing, softball, swimming, hunting, basketball, and sailing.

Other favored leisure-time pursuits include gardening, woodworking, photography, bridge, dancing, and organized reading in some 34 different fields. The variety of activities is amazing, ranging from cooking to sports cars.

5

His work is uninteresting, dull, monotonous, tedious, time-consuming, and, though he works for years, he may see no results, or may fail, and he is likely to receive neither adequate recompense nor recognition. He may live in a cold-water flat; his laboratory may be dingy.

Research is time-consuming, but few scientists find it dull. As one of them wrote on his questionnaire, "Most people don't appreciate the fact that science is a way of life. Frequently research problems become so engrossing that one can think of nothing else." Another said of his colleagues, "These scientists are among the most stimulating people in the world. They continually seek to discover something new, to improve something already invented, to learn the 'why' of various phenomena—always seeking, always learning. One must admire this attitude." They enjoy their work.

One out of four of the reporting scientists decided upon his career before reaching the age of 15. The reasons included a strong personal interest in the field, courses in elementary or high schools, influence and encouragement of teachers or members of the family—and this may be a surprise—experience with home or toy chemistry sets.

The scientists were not asked whether they felt their salaries were adequate, but 43 per cent said they decided to go into industry because of its financial rewards. Lenher said he knew of no scientist who lives in a cold-water flat; in fact, one of the favorite sales arguments of the real estate agents in the Wilmington area is to mention that "this house was owned by a chemist—or engineer—so you know it is in good shape."

6

If he works by himself, he is alone and has heavy expenses. If he works for a big company, he has to do as he is told, and his discoveries may be turned over to the company and may not be used; he is just a cog in a machine.

The questionnaire, respecting the right of scientists to privacy in their opinions about the company, did not try to discover whether they felt they were merely "cogs in a machine." It did solicit their reasons for joining the company. Twenty-seven per cent mentioned the attraction of the type and diversity of work offered; 20 per cent said it was higher compensation; 14 per cent said it was the fine reputation of the company; 14 per cent the opportunities for a career and advancement; eight per cent the desirable location; seven per cent the company's good laboratory and other facilities, and seven per cent spoke of the type of people they would work with—their associates.

It is worth noting here that among those who have risen to top management in the company, those who began in a research laboratory constitute 33 per cent of the assistant general managers, 54 per cent of the directors of production, 38 per cent of the assistant directors of production, 33 per cent of the directors of sales, and 27 per cent of the assistant directors of sales. In numbers, 43 of the 118 top posts are held by men who began as research scientists. In addition, all 24 of the directors and assistant directors of research in the various departments—posts which rank on the organization chart with the directors and assistant directors of production and sales—are of course scientists.

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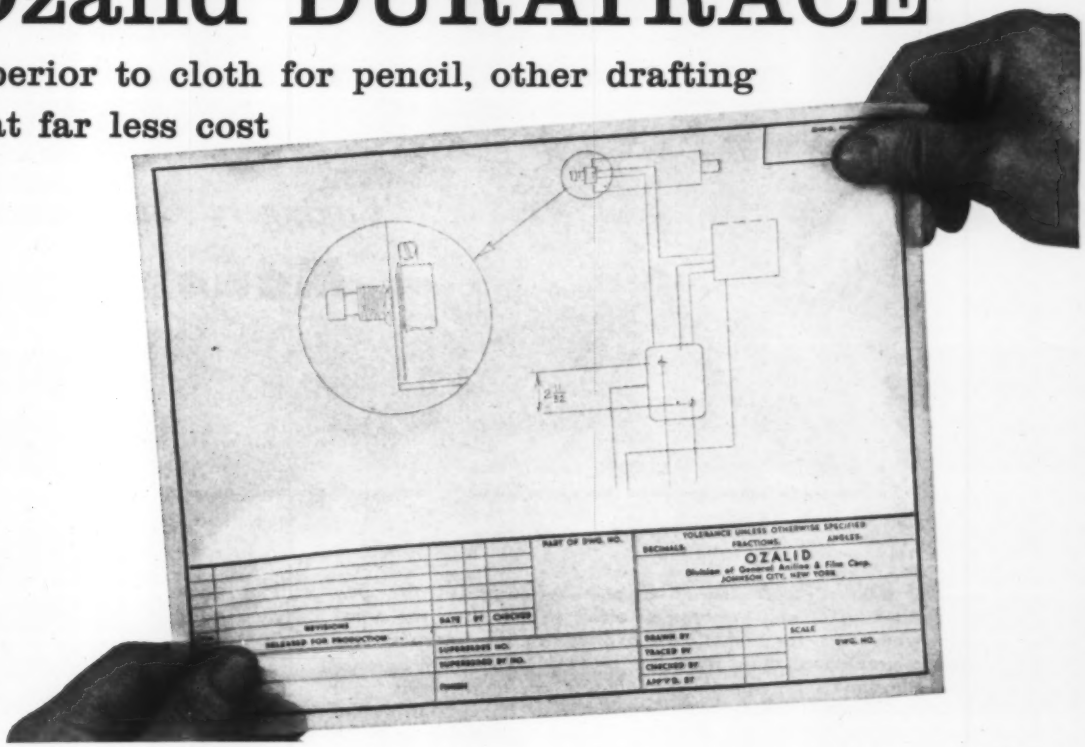

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Circle 414 on Page 19

Engineers' Compensation—

Money Comes

SOCIETY rates a man according to how much he earns, by the way he lives, the clothes he wears, the type of office he has, and the number of people who work for him. Compensation for the engineer has come to mean a great deal more than just money.

From the company's viewpoint, the amount an engineer is paid denotes his value or contribution to the organization. If his contribution is considered to be a greater one, it is to be expected that he will be compensated at a higher level. From the individual's standpoint, salary is one way he can compare himself with others in the organization.

This is particularly true in an engineering department where many have the same title but are paid at considerably different levels. For this reason the proper administration of salaries within the department is of utmost importance. According to the survey report, *Engineering Manpower: How To Improve Its Productivity*,* on which this series of articles is based, once salaries fail to represent the individual's contribution in relation to the others in the department, an imbalance can occur that will seriously affect the people concerned.

Replies to the survey regarding compensation reveal four areas of major importance: 1. How engineers' salaries compare. 2. Starting salaries. 3. Salary administration. 4. Overtime.

How engineers' salaries compare

Engineering salaries have undergone two important changes in recent years as compared with the wage structure of the over-all company. While the spread between management and engineering salaries has increased, the spread between engineering and hourly workers' salaries has decreased. Though gradual, the changes have been a source of continual dissatisfaction to engineers.

The widening breach between engineering and administrative salaries steadily impels engineers away from their profession. In many firms, the technical man reaches a ceiling which he cannot exceed unless he turns to other fields. This limitation and the slow advancement rate have created discontent and encouraged engineers to venture into sales or administrative work where often, because of their aptitudes, training, and background, they prove less talented, less productive, and less satisfied with their position.

As to the decreasing spread between engineers' and hourly workers' salaries, labor unions have been effective in raising the general level of production wages, but engineers have in general not enjoyed such increases. In a survey recently conducted by the Engineers Joint Council, the inequity is brought out by a comparison of engineers' compensation with the earnings of carpenters and electricians:

- The median (lifetime) salary of engineers exceeds the carpenters' by about $80,000 and the plumbers less than $50,000. This is not an attractive (lifetime) return on the investment for an engineering education.

Management consultants agreed that engineers who did not switch to management were limited in their ultimate salaries. Two quotes typify their replies:

- Salaries above $12,000 a year are very difficult to obtain; this situation thus severely limits engineers with advanced training and, say, eight to ten years of post-doctoral experience. This type of financial ceiling does cause a certain wastage of engineers since many find it necessary to go into administration or other more commercial endeavors.
- In today's labor market the ultimate pay levels which can be expected by engineers who do not go into management appear to be about $15,000 to $18,000 a year. Of course there are wide variations depending upon the engineering specialty involved, the size and profits of the concern, and the ability of the individual.

Starting salaries

Starting salaries for young engineers have risen rapidly during the

* ©1957, G. A. von Peterffy

First

past ten years, but the rest of the engineering salary structure has not had a commensurate increase. As a result there occurred what has been termed the "telescoping" of salaries.

Discussing telescoping, Joseph Amann, president of the Engineers and Scientists of America, said:

> • In the mid-thirties an engineer with 20 years of experience earned approximately four times the beginner's rate of that period ($400 as compared with $100). Today an engineer with 20 years of experience is above the average if he earns much more than twice the rate paid to college graduates ($870 as compared with $435).

Almost all companies contacted in the survey expressed grave concern over salary telescoping. Yet few were able to suggest an answer or predict an end to the problem.

Survey findings indicate that most telescoping occurs between the lower and medium salary levels. Top earnings in the field have apparently kept pace with rising starting salaries, and the spread between the two has been great enough to avoid difficulty. It is with the middle group, comprising the largest number of industry's engineers, that companies have had their greatest trouble.

Salary administration

Most companies interviewed use some form of periodic review as the basis for evaluating engineer performance and adjusting salaries. The actual form of these reviews, however, varies considerably. In one large company, engineers' salaries are reviewed twice a year and if the individual has met certain qualifications, he is given a standard raise. "Actually," an executive said, "raises are fairly automatic; virtually everyone gets one once a year, and a great majority of our people get them twice a year."

Another company contacted reviews their engineers annually and raises them according to the merit shown by the evaluation. Though almost all engineers receive a yearly raise, the amount varies considerably from one engineer to another. In this way, engineers are treated as individuals and are com-

Checkpoints for Engineering Management

- ☑ **1. Has telescoping of starting salaries with median salaries caused a problem?**
- ☑ **2. Does the widening spread between management and engineering salaries indicate respective contributions to the company?**
- ☑ **3. Has the decreased spread between engineering salaries and production wages been explained in terms of lifetime earnings?**
- ☑ **4. Do your engineering supervisors play a responsible part in salary administration?**
- ☑ **5. Have overtime payments resulted in loss of individual initiative?**

pensated on a selective rather than on a group basis.

Questioned on the handling of unusually talented engineers, most companies replied in a typical vein. The words of one executive are characteristic:

> • We do not (have to) make special provisions for unusually talented engineers. Their outstanding ability would undoubtedly be recognized and their progress to higher positions would be at a faster rate than for less qualified men. . .

Only a few companies replied in the vein of an airframe company official who said:

> • Creativeness is perhaps the most important factor in determining promotions and pay increases. . . We review salaries quarterly and try to push the outstanding ones (engineers) ahead far faster than the others. There is a lot of flexibility in our salary structure and I can't recall a case where a salary-grade limit has held back an outstanding, capable engineer. The system we use for reviewing is as objective as we know how to make it and involves the judgment of more than one supervisor.

Most of the individual engineers contacted, however, expressed dissatisfaction over the basis for wage increases. Talented engineers, they feel, are not rewarded according to their abilities. Rather, they claim, raises are based almost solely on longevity and seniority. A common complaint was that the personnel department normally administers engineers' salaries, while the engineering supervisors control promotions. As a result, they said, salaries often do not reflect responsibilities.

Overtime

Many engineers are paid overtime for work beyond the normal 40-hour week. Generally, those companies that do pay overtime divide their engineers into two categories: "exempt" or "noneligible" for overtime payments, and "nonexempt" or "eligible" for overtime payments. The exempt group normally includes all those who have some supervisory or administrative duties.

The inequity which arises from such a system occurs at the bottom of the exempt group and at the top of the nonexempt group. One company pointed out that when their engineers worked large amounts of overtime, their better-paid, nonexempt engineers often made more than their supervisors who were in the exempt group. As a result, some of the more qualified engineers felt they could not afford to become supervisors.

One company felt the overtime innovation had had a dampening effect on engineers' initiative. Before overtime was paid, they said, individual engineers used to stay after working hours to finish up their work. "Now," said one executive, "no one has the slightest interest in sticking around."

Final article in this series will appear in the June 12 issue. It will deal with the subject of patents and will discuss engineer-company patent agreements as a condition of employment, personal recognition, patent assignment to the company, and methods of reward.

Recommendations for Management

1. Challenge Salary Questions

Many companies have compensation administration that is perfectly suited to the needs of the engineer. For these companies, engineering salaries are not a problem. Other companies, however, have found their engineering salary scales are badly distorted. For these companies, the compensation question is a grave one and must be solved before the department can hope to be operating effectively.

2. Review Salary Policies

Review the policy of placing a ceiling on engineering salaries. Management should not prevent engineering salaries from rising to levels that men in other areas of the company are capable of attaining. This is especially true for unusually talented and qualified engineers.

3. Identify Talented Engineers

Determine exactly who fits into the "unusually qualified" bracket. The top executive in the engineering department should decide precisely who fits into this category. If an uncontrolled and general upward trend in salaries is allowed to sweep through the engineering department, it is likely that serious distortions will result.

4. Downplay Engineers' Seniority

Distortions of the wage structure within the department have often resulted when the personnel department handles salary administration for engineers. Too often, seniority has been used as a crutch for determining raises in place of recognizing ability. Equally important, salary administration solely by the personnel department takes away from the supervisors and department heads one of the functions that should fall within the realm of their responsibility.

5. Develop Salary Criteria

The critical problem in the whole compensation area is developing salary criteria by which the supervisor can measure an engineer's ability and contribution. Developing these is very difficult at best. Management owes it to itself and its engineers, however, to develop supervisors who are competent at evaluating and dealing with engineers who come under their supervision.

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By employing a positive chain drive to transmit power, Link-Belt's P.I.V. (Positive, Infinitely Variable) variable speed drive provides instant and positive speed settings, with no perceptive loss of speed regardless of load. Stepless variation of any speed from maximum to minimum can be obtained instantly, even while operating at full load.

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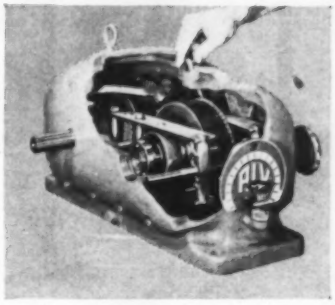

P.I.V.'s are compact, permitting installation as either a separate unit or as a built-in part of the driven machinery. Exceptional application flexibility can be accomplished by incorporating both motor and helical gear sets integrally with the P.I.V. drive.

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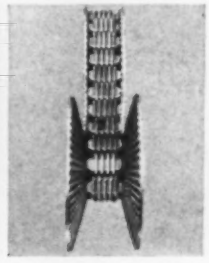
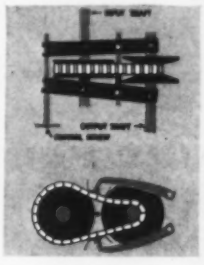
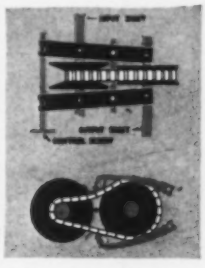
Teeth on radially grooved wheels provide grip for self tooth-forming chain.



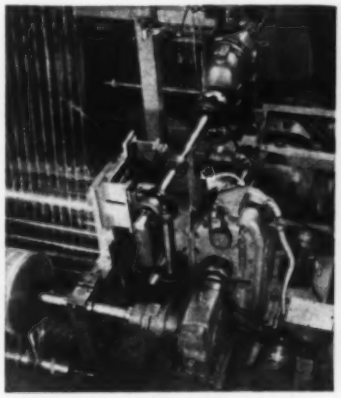
Chain teeth engage wheels to provide a positive chain drive to transmit power.



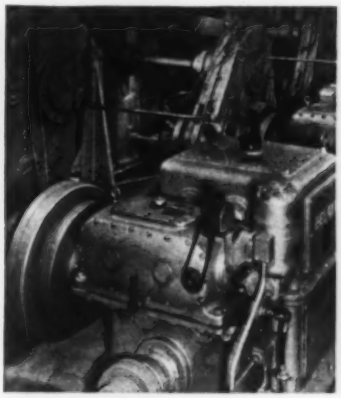
Maximum speed setting of the grooved wheels produces high speed at output shaft.



Minimum speed setting of the grooved wheels produces low speed at P.I.V. output shaft.



PRINTING—P.I.V.'s on windup and dryer rolls prevent tension build-up on press running cellophane sheet.



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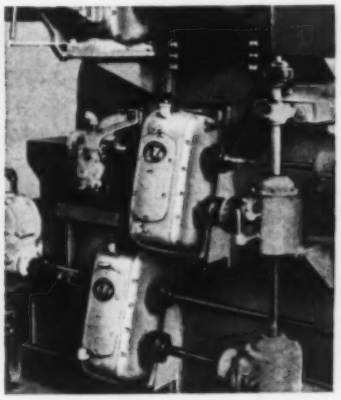

TEXTILES—P.I.V.'s on rayon spinning machine control thread denier and speed of viscose metering pumps.

BOOKS 2274 and 2349 describe P.I.V. drives and controls, respectively. Get your copies from your nearby Link-Belt office.

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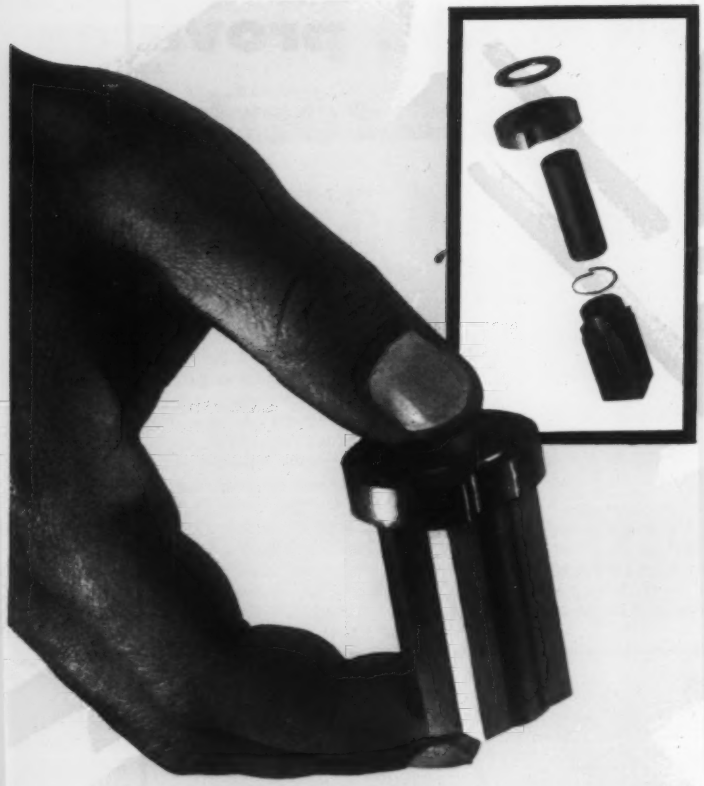

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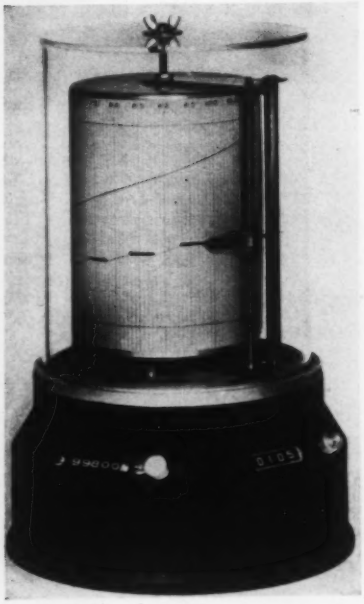

EFFICIENCY RECORDER shows time utilization. The upper slanted line is for 100 per cent utilization, the middle line is slanted upward to show "on" time, and the heavy horizontal line shows "down" time. Made by Gorrell & Gorrell, Westwood, N. J., the unit can be used with any electrically driven device. An accessory subbase shows total accumulated running time and total number of operating cycles.

Predict Automated Wallet Within 50 to 75 Years

Engineers See Time As Only Barrier

CLEVELAND — In 50 to 75 years Americans will be conducting all financial affairs without the use of cash, coins, or checks, if the prediction of two design specialists comes true. Only the length of time required to change over from present intricate money handling systems is seen as a barrier to sooner use of this method. All typical components of such a system, say G. M. Hunt and P. E. Lannan of Designers for Industry Inc., Cleveland, Ohio, are now understood and can be built.

Under the new monetary system, all bank deposits and withdrawals,

Circle 416 on Page 19

all charge payments and cash purchases would be made with the use of individual "electronic pocketbooks," and auxiliary data-processing equipment used by employers, businesses, and banks.

According to the engineers, the system will work like this. The electronic pocketbook will contain a complex network of printed circuitry, which will form the basis of an electronic "meter," indicating the amount of dollars available to the user. Deposits will send the meter reading up; payments will send it down.

Instead of a paycheck, wages will be posted on the employee's electronic pocketbook by the employer. The same machine which does the posting will be wired to a central bank clearing house, where a similar withdrawal will be posted on the corporate electronic pocketbook. The employee can immediately use his card to the limit of his deposits. Each time he makes a purchase or pays a bill, the correct amount will be "withdrawn" from his card at the store where he is doing business. These data will be simultaneously transmitted to the bank clearing house where the amount will be electronically deducted from his account.

The new system, it is pointed out, would revolutionize every phase of financial activity. Checking accounts will be balanced out at electronic speed. Accounting tabulations now handled in days will be accomplished in split seconds.

The system will also be used for paying bills remotely. Placing the electronic pocketbook in a specially adapted telephone will transmit the code number, plus the amount to be paid to the proper party. Thus, payments can be made simply by dialing the creditor's number.

Research by requirement can sap America's scientific vitality, says L. V. Berkner, President of Associated Universities. He observes that flight was achieved out of seemingly unrelated researches of Marconi, Franklin, Faraday, Henry, Maxwell, and Hertz. Requirements, Berkner says, could have diverted the genius of men like these to improving sails for sailing ships.

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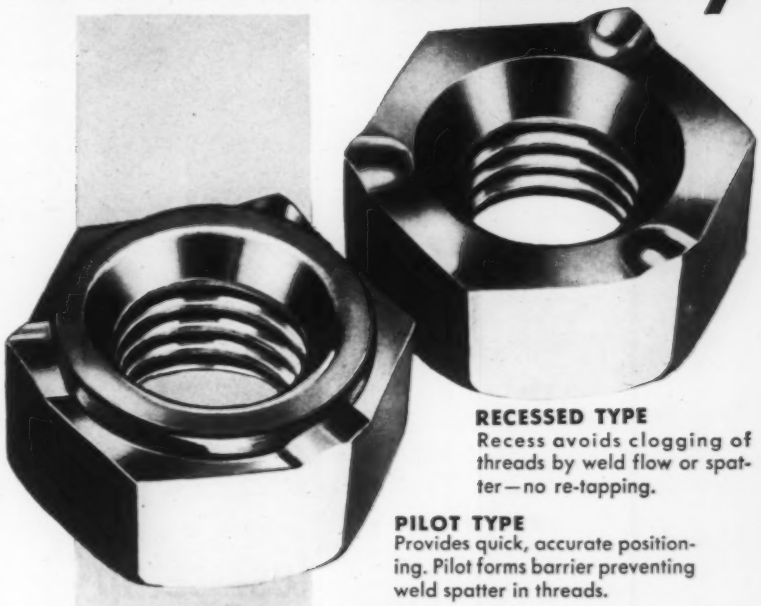

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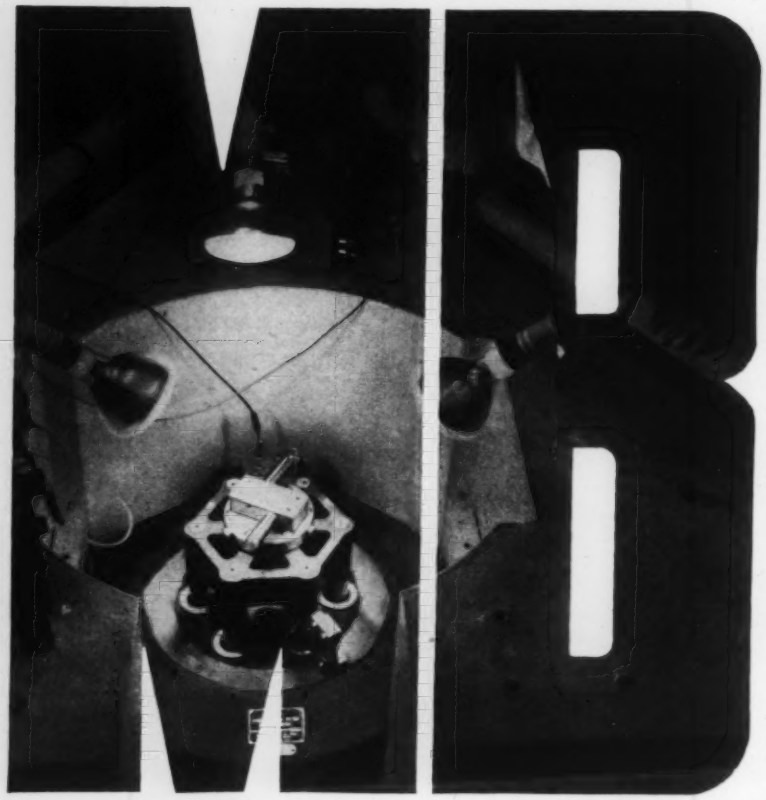
Circle 417 on Page 19

WHAT'S GOING ON IN VIBRATION TESTING . . .



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How far should you go to insure reliable instrumentation? For the Bomarc missile, engineers went all the way. Instruments are shake-tested and calibrated on an MB Vibration Exciter system. To eliminate all stray and spurious vibrations, the shaker was mounted at the c.g. of a 2½ ton concrete enclosure. Suspended from springs, this mass eliminates transmissions of all external vibrations above 1½ cps.

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WASHINGTON — The world's most precise engraving machine has produced the largest and most perfect diffraction gratings ever made. Diffraction gratings are used for many scientific purposes, ranging from the analysis of the light from stars to the study of the structures of atoms and atomic nuclei. The more precisely engraved and larger diffraction gratings will reveal in greater detail the infinitesimal structures of atoms and molecules.

This accomplishment is the result of ten years of work in the MIT Spectroscopy Laboratory under the direction of Dr. George R. Harrison, dean of the School of Science, who announced the work recently before the American Optical Society.

To make a diffraction grating of the new type, a blank of fine optical glass 5 in. wide and 10 in. long is coated on one side with a film of aluminum about 0.001 in. thick, producing a mirror. Then 74,500 parallel grooves are engraved on this film with a fine diamond point. Each groove is about 0.0001 in. deep and straight to about 10^{-6} in. Also, lines must be parallel within a small fraction of a millionth of an inch.

Light falling on such a grating is broken into a multicolored spectrum much as it would be by a prism, but much more thoroughly. Standard diffraction gratings up to 6 in. or more have been available for years, but the difficulty of ruling grooves increases rapidly with the size of the grating.

Ten years ago Dr. Harrison and his associates began work to monitor the engraving of each groove on the grating by controlling the engine with light waves. The light source used to control the engine is a mercury arc, made at the National Bureau of Standards, which uses an isotope of mercury. The ruling engine is so sensitive that the slightest vibration would mar the engraving process. It is about the size of a grand piano, and its complex mechanical parts are immersed in a tank of oil enclosed in

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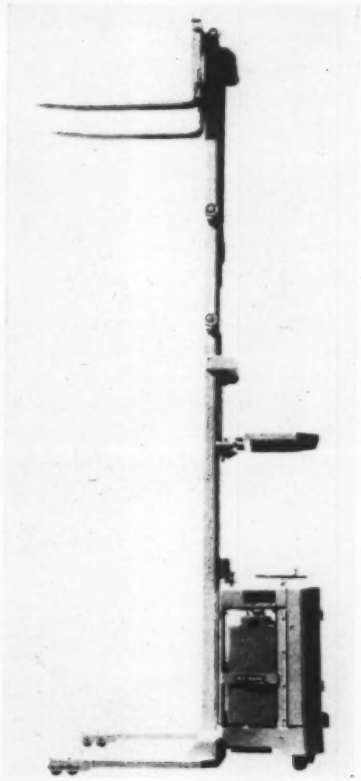
a large plastic box designed to keep out dust.

A week or more is required to rule a grating. Once started, the engraving process cannot be interrupted until the grating is complete. To enter the engraving room, one must pass through six doors, and entry is permitted only when the engine is not ruling. A staff member watches the progress of the engraving by means of oscilloscopes and other electronic systems placed outside the engine room. Temperature in this room is kept as constant as possible to within 0.001 degree.

The first research in which the new 10-in. grating is being used involves the study of the emission of light in a powerful magnetic field.



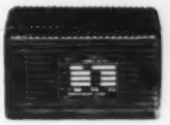
HIGH-LIFT TRUCK converts air space near ceilings into usable storage space. Developed by Raymond Corp., this new narrow-aisle model will hoist 4000 lb through a 16-ft lifting range. Outrigger base legs combined with the 200-deg steering arc of an offset drive wheel permits maneuvering in 78-in. aisles.

A WINCO POWER SUPPLY
DESIGNED TO YOUR EXACT NEED

Wincharger engineers have solved many formidable power problems for both the military and civilian companies. If you have an application with special problems of vibration, altitude, heat, shock, humidity or regulation, tell us about it. Wincharger engineers will design a power supply to fit your exact needs. Problem solving is a specialty at Wincharger.

ALTERNATORS
Brushless alternator for emergency AC aircraft power or missile power supply systems.

SPECIFICATIONS
Weight—20.5 lbs.
Rated Output—4.0 KVA at 80% power factor
Ambient Temp.—100° C.
Temp. Rise—40° C.
Voltage Regulation—plus or minus 5%
Speed—1200 RPM plus or minus 5%
Voltage—208/120, 3 phase—400 cycle



TRANSISTORIZED POWER SUPPLIES
Design capitalizes on the inherent advantage of transistorized equipment . . . stresses retrofit, which means they can be used to replace vibrators and dynamotors in existing aircraft if so desired.

SPECIFICATIONS
3 sizes—25, 50 and 100 watts with overload capacities up to 100% for short periods.
Volt Ripple—less than 1%
Efficiency—85%

ALTERDYNES
An urgent Armed Forces requirement for AC power coupled with a conventional dynamotor for automatic-tuning, necessitated the development of this special Alterdyne.

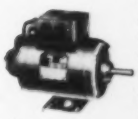
SPECIFICATIONS
Input—Nominal 27.5 Volts DC.
Output No 1—250 Volts DC at 300 Mils.
Output No. 2—43 Volts DC at 10 Mils
Output No. 3—115 Volts—400 Cycle AC 30 Watts
Temperature Range—Minus 40° C to plus 45° C.
Duty—Continuous

DYNAMOTORS
As higher-altitude jet aircraft were developed, dynamotors were required that would operate at 80,000 feet. The result—this Winco dynamotor to operate at higher altitudes.

SPECIFICATIONS
Input—Nominal 27.5 Volts DC
Output No. 1—600 Volts DC at 550 Mils.
Output No. 2—250 Volts DC at 150 Mils.
Unfiltered Ripple Maximum—1%
Duty Cycle—5 Minutes On
5 minutes Off
And Repeat.
Temperature Range—Minus 55° C to plus 85° C.
R.P.M.—8,500
Altitude—80,000 feet.

INVERTERS
Literally thousands of each of the Winco Inverters from 20 VA to 6½ KVA have been manufactured on a mass-production basis at low-cost without sacrifice of high quality standards.

SPECIFICATIONS
Model No. 3186
Input—Nominal 27.5 Volts DC.
Output—115 Volts, 400 Cycle 1 phase, 2500 VA.
Temperature Rise—50° C.
R.P.M.—6,000 Approx.
Altitude—50,000 feet.



AC & DC BALL BEARING
GENERATORS
Complete line from 500 watts to 10 KW. 1800 or 3600 RPM. Units equipped with terminal box or complete controls. Application engineering service available fo special adaptations.

PORTABLE POWER
GENERATORS
Equipped with Automatic CONSERV-er. Brings engine to full power when load is applied, reduces to idling speed when tool is turned off—all automatically. 300 watts to 10 KW.

Send for complete power supply brochure

WINCHARGER CORPORATION
SIOUX CITY, IOWA
A ZENITH Subsidiary

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LIFERS
CORNISH
Custom
CORD SETS
MADE BY ENGINEERS FOR ENGINEERS
No "time off" expected for good behavior. CORNISH designs BLUE CHIP Cord sets to your special requirements, produces them with a KNOW-HOW that insures trusty service on America's finest electrical equipment and appliances. No charge for consultation.
Don't take chances... CORNISH 'em!
All Cord Sets available in
COLOR
to match your appliances, both in Rubber and in Plastic
CORNISH WIRE COMPANY, INC.
50 Church Street New York 7, N. Y.
CORDS AND CORD SETS FOR HOME, FARM AND INDUSTRY
REPRESENTATIVES
ATLANTA BRIDGEPORT CHARLOTTE CHICAGO CINCINNATI
CLEVELAND DALLAS DENVER DETROIT KANSAS CITY
LOS ANGELES MINNEAPOLIS PHILADELPHIA PITTSBURGH
ROCHESTER ST. LOUIS SAN FRANCISCO SEATTLE WILLIAMSTOWN

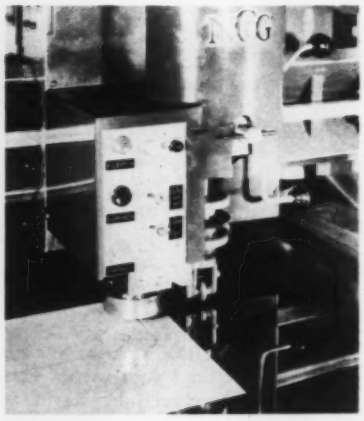
Electronic Line-Tracer Guides Flame Cutter

Reads Ordinary Line Drawings, Eliminates Need for Templates

CHICAGO—The first electronic line tracer for flame shape-cutting machines in the U. S. uses a newly developed optical "sensing system" — steers metal-cutting torches by scanning ordinary pen or pencil-line-drawings. Developed by the NCG Div. of National Cylinder Gas Co., it eliminates the need for costly templates. The tracer reportedly reduces the cost of pattern preparation by 75 per cent as compared to other electronic processes, which make use of a more complex half-black, half-white area to follow.

With the new unit, simple drafted pencil drawings with lines no more than 0.04 in. wide permit the phototransistor scanner to follow at speeds as fast as the thickness of the metal requires. The device turns corners on a radius as small as 3/32 in. and even crosses lines.

The line-tracer head consists of a vibrator-type scanner employing a phototransistor, which is a component in a closed-loop servo system. Rigidly mounted to the regular motor-driven tracing head of the flame-cutting machine, it scans a line drawing and directs the torches in cutting the pattern from a plate of steel. The line-tracer head follows pencil or ink lines



Electronic tracer guides flame-cutting machines by following an ordinary pencil-line drawing. The unit eliminates the need for templates; reads ordinary line drawings instead.

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0.040 in. or less in any combination of dark or light colors, between which the photocell can discriminate.

Defense Digest

Third atomic submarine, *USS Skipjack,* will be the fastest and most maneuverable in the nuclear fleet. Launched May 26 by General Dynamics' Electric Boat Div., *Skipjack* is first of the Navy's new attack submarines. Its shark-shaped hull is patterned after the experimental diesel-powered *Albacore,* with elevated diving planes on the sail which serve as underwater wings. Propulsion plant, driving a single propeller, is a water-cooled reactor similar to those used in *Nautilus* and *Skate.* The vessel is 250 ft long and has a surface displacement of 3000 tons.

• • •

World altitude record for conventional aircraft—70,308 ft, set in 1957 by an English Electric Canberra—was bettered twice in past two months by U. S. planes. Gruman's F11F-1F Super Tiger reached 76,828 ft in April. Super Tiger, powered by GE's 15,000-lb thrust J-79 engine, is a front-line Navy fighter; will soon be sold in quantity to Japan. The Navy's mark was barely a month old when an Air Force Lockheed F104A climbed to 91,249 ft to claim a new unofficial record.

• • •

Humanities and space flight are two subjects emphasized in a revised curriculum adopted by the Air Force Academy. A new department of astronautics will teach fundamental physics of manned and unmanned space flight. Semester hours have been decreased in electrical engineering and graphics. In humanities, courses have been added in military history, geography-cartography, American and foreign governments, and international relations. The new program allots 70 semester hours to humanities, a like amount for the basic sciences, and 26 hours to military airmanship.

• • •

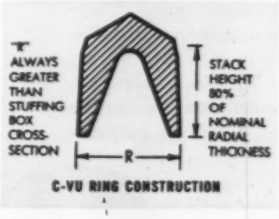
Ultraprecise timing, now possible with English-made quartz clocks, will aid in satellite and missile tracking, including detection and destruction of inbound ICBM's. According to the Army, the new clocks are accurate over short periods of time to three-hundred billionths of a second. Converted to distance measurement, this would be an accuracy of ½ in. in 500,000 miles.

CHEMLON* C-V RINGS ARE INDUSTRY'S MOST UNIVERSAL PACKING . . .

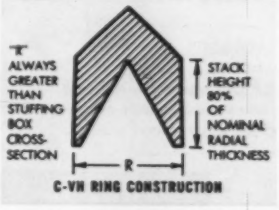
Countless successful applications of C-V Rings under the most severe service conditions have made this the closest approach to a universal packing.

It will effectively handle all industrial acids, alkalis, solvents, organic and hydraulic fluids . . . temperatures from −120°F. to +500°F. . . . is equally suited to valves, pumps, mixers, hydraulic cylinders and like equipment.

"John Crane" C-V Rings have extremely low coefficient of friction. "Breakout" friction is only slightly higher than running friction.



C-VU RING CONSTRUCTION



C-VH RING CONSTRUCTION

TWO STYLES ARE AVAILABLE:

C-VU RINGS *for low pressure service* —such as control and regulator valves handling gases and fluids, where it is necessary to have a very sensitive and resilient type packing.

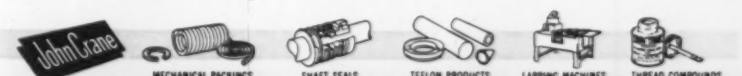
C-VH RINGS *for high pressure service* —for use in pumps, hydraulic cylinders and like services at pressures ranging to 500 psi. and over. These rings are constructed with a heavy wall heel to withstand pressure requirements. They are designed to provide voids between rings, so that as the Teflon expands due to heat, this take-up room minimizes any excess friction in the stuffing box.

"John Crane" C-V Rings are available in full line of standard sizes and male and female adaptors. Sizes can be molded to stuffing box specifications.

Request Bulletin P-325.

*"John Crane" C-V Rings are made from Chemlon—*the best in DuPont Teflon.*

Crane Packing Co., 6425 Oakton St., Morton Grove, Ill. (Chicago Suburb). *In Canada: Crane Packing Co., Ltd., Hamilton, Ont.*



CRANE PACKING COMPANY

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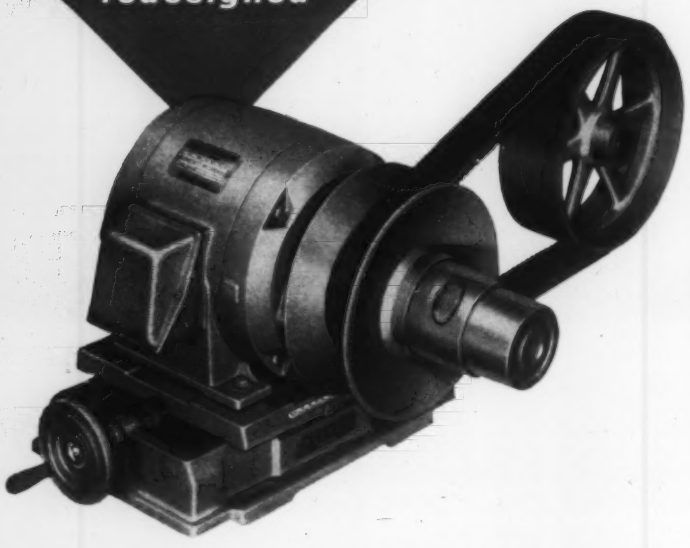
completely redesigned



REEVES® *Vari-Speed MOTOR PULLEY*

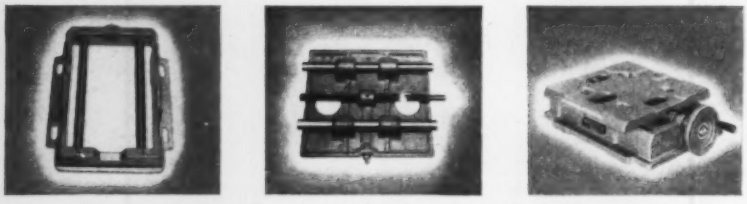
Here is variable speed control in its most simplified form . . . variable speed control with new economy.

Disc assemblies have just three main parts: two smooth-face, cone-shaped discs; and the belt tension spring. There are no other wearing parts to give maintenance trouble. Compact disc assemblies available in nine sizes, ½ hp. through 15 hp., to fit both old and new NEMA motors.

Separately mounted countershaft assemblies are available. For complete information on sizes and available controls, write for Bulletin H36-V582.

Split section view of sliding disc shows how REEVES "close grooving" maintains film of lubricant between hub length of fixed disc and bore of sliding disc. One lubrication point services entire disc assembly.

New precision bases Four compact sizes to accommodate old and new NEMA motors in ½ through 15 hp. Sturdy bases are specially manufactured to assure positive, easy adjustment and accurate speed control.

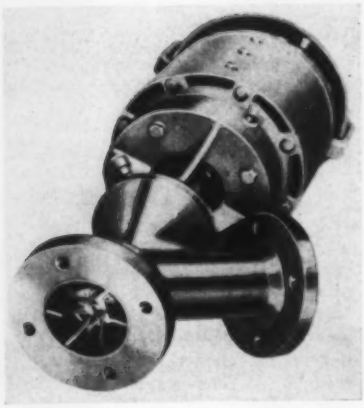


Base and motor slide rods manufactured for precision fit and true alignment. Fully-lubricated shifting screw and precision features provide easy shifting.

REEVES PULLEY COMPANY

Division of **RELIANCE** ELECTRIC AND ENGINEERING CO.

Columbus, Indiana



HOMOGENIZING AND MIXING are combined in this continuous-flow unit developed by Eppenbach Div., Gifford Wood Co., Hudson, N. Y. It will combine mixtures of liquids, gases, and solids and in many cases will pump the refined material to distant or higher parts of the system. For materials requiring additional refinement, several homo-mixers can be connected in series. Units are available in six sizes, rated according to turbine diameter and diameter of the exit stream.

Throw-Away, Hand-Cranked Engines Needed at Poles

PHILADELPHIA—In the absence of a lubricant that enables both quick starting and extended operation at subzero temperatures, Arctic travelers have had to use throw-away engines to start the main power plants of their over-land vehicles. This was disclosed at a recent ASME conference by Earl J. Beck, Jr., a project engineer for the U. S. Naval Engineering Research and Evaluation Center in California.

The problem arises from the fact that heavy and medium-weight oils congeal in subfreezing temperatures so that the engines they lubricate will not turn over enough to start. Beck noted that the most satisfactory compromise worked out in Antarctic Geophysical Year operations involved the use of two engines. One is the regular engine that powers the truck or other equipment being used. The other is a small engine used to start the first.

The small engine is lubricated by military lightweight oil, which doesn't freeze in subzero temperatures, but which doesn't offer much

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protection to the engine either. Engines run on a day-to-day basis on the lightweight oils show such severe wear and corrosion that they must be abandoned. This isn't as expensive with a small, easily replaceable starting engine used in combination with a diesel, which in this system can use its regular medium-weight oil.

The ideal lubricant is "a golden oil that would pour at any temperature." Engines would have to be redesigned to derive maximum lubrication benefits from it. At present, "modification of a starting engine which could be hand cranked seems most appropriate."

Man-Machine Communications To Be New Center Studies

Can Grammar Be Expressed In Mathematical Terms?

CAMBRIDGE, MASS.—Basic research in methods of communication between machines, between humans, and between humans and machines will be studied at the Center for Communication Sciences, recently established in the Research Laboratory of Electronics at Massachusetts Institute of Technology. Announcing the new Center, MIT acting president Stratton said that scientists and engineers have become increasingly aware of two needs:

- How to relate man effectively to the devices that he has to operate.
- How to match, informationally, machine outputs and inputs with man's capacities.

Considerable research has already been done in communications, according to Dr. Jerome B. Wiesner, head of RLE, but most of the results are uncorrelated. "We need generalizations and theories which will account for intellectual processes in detail." Questions that still need answers are:

- Can we describe in mathematical form the grammar of a language, such as English or Russian?
- Can we give a rational account of the way in which man's brain processes the information coming through his senses?
- What role does information play

CHECK VALVE PRICES NOW REDUCED

We have reduced the price of our regular Waterman Check Valve. Tell us your requirements to-day and take advantage of this price reduction.

These check valves are of 3000 PSI operating pressure for oil, air or water.

They are of one piece construction—no welds or brazes to crack.

Nylon poppet assures trouble-free service.

Aluminum body and nylon poppets reduce the weight.

They afford minimum pressure loss through valve at rated flow.

ORDERING DATA	
MODEL No.	PIPE SIZE
345-3	⅜" NPT
345-4	½" NPT
345-6	¾" NPT
345-8	1" NPT

Write for Bulletin 5.01

WATERMAN
ENGINEERING COMPANY
725 CUSTER AVENUE · EVANSTON, ILLINOIS

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in human learning and decision-making?

• Are there laws to be discovered which resemble the laws of physics in their generality and predictive power?

As a simple example of the kind of problem to be dealt with in the Center, Dr. Wiesner pointed out how a telephone number is communicated. People can remember a number more easily when it has a word as a prefix such as:

UNiversity 4-6900

The dial system, however, is not "interested" in the word and will accept the number just as readily if dialed as:

864-6900

A computer, using the binary system, would accept the number only when coded in these terms:

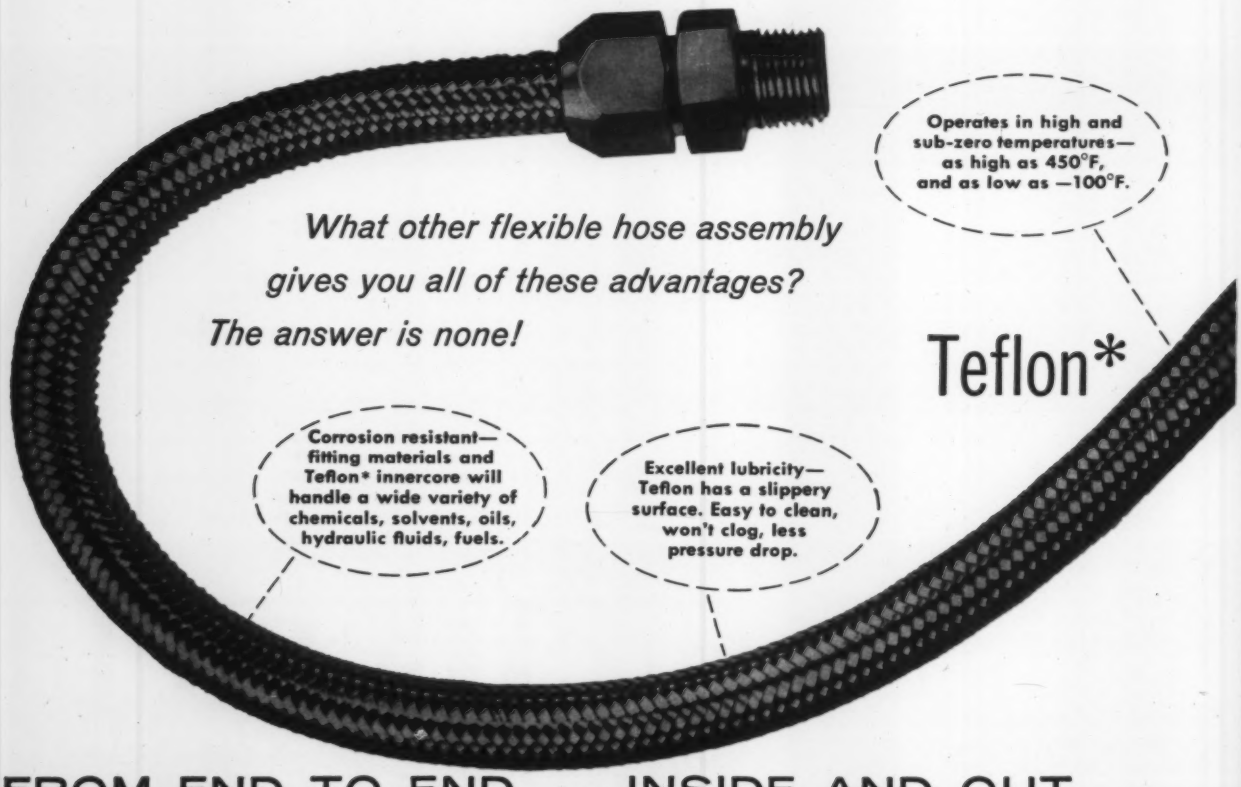
10001101010001100010100

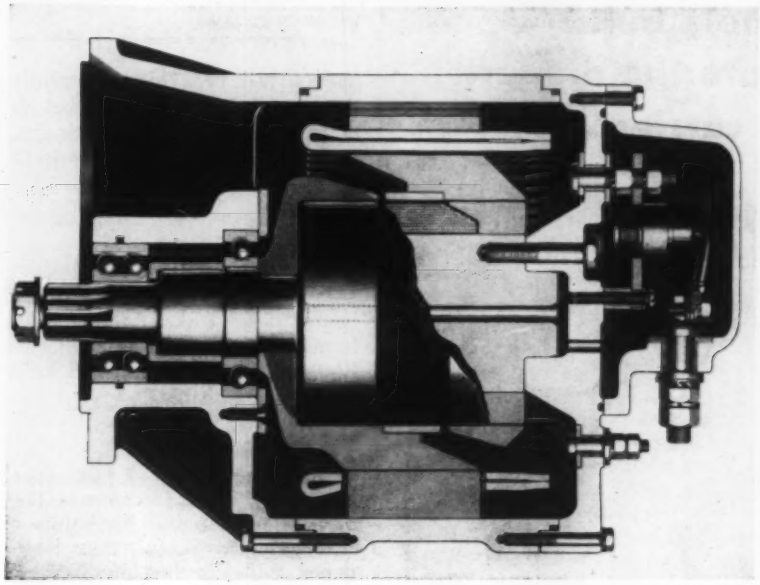
Such a number would be very difficult for a human being to learn, though remembering it would be greatly facilitated by "recording" it, or breaking it down into groups as:

1 000 110 101 000 110 010 100

FIRST TWIN-PROPJET U. S. AIRLINER, Fairchild's 40-passenger F-27, is designed specifically for local-service airlines and large corporations. First flight, above, was made in April; delivery on a backlog of 93 planes will begin in June. Powered by two Rolls-Royce Dart engines, the new liner cruises at about 300 mph; has a range of more than 1600 mi. Cabin is air conditioned and pressurized. With the unusual high-wing design, it gives all passengers a good view.

This example indicates one of the differences in the way that machines and people communicate. Further research should make possible a better understanding of their methods of communication and may result in a greater efficiency of both.


Operates in high and sub-zero temperatures— as high as 450°F, and as low as —100°F.
What other flexible hose assembly gives you all of these advantages?
The answer is none!
Teflon*
Corrosion resistant— fitting materials and Teflon* innercore will handle a wide variety of chemicals, solvents, oils, hydraulic fluids, fuels.
Excellent lubricity— Teflon has a slippery surface. Easy to clean, won't clog, less pressure drop.
FROM END TO END . . . INSIDE AND OUT



RUGGED POWER TEAM for commercial vehicles consists of self-rectifying, oil-cooled ac generator and transistor regulator. Developed jointly by Delco-Remy and the GMC Truck and Coach Div., the brushless generator can deliver 215 amp at cruising speed, 125 amp at engine idle. Oil cooling permits the generator and built-in silicon rectifiers to be completely sealed against dust and dirt—major problem in maintaining air-cooled generators. The all-electric regulator is a new approach for automotive vehicles, contains no moving parts, and requires no adjustments.

Checklist for specialty transformers tells whether they are safe for consumer use. Specialty transformers are those used with mercury-vapor lamps, sun lamps, remote-control, low-energy power, and signal circuits; ignition transformers for use with gas burners and oil burners; gas-tube sign transformers and those for use with electric toys. The checklist is provided by the Underwriters' Laboratory standard just revised and approved by the American Standards Association.

Meetings

AND EXPOSITIONS

June 9-12—

National Materials Handling Exposition to be held at the Public Auditorium, Cleveland. ASME-sponsored Materials Handling Con-

Titeflex Springfield "140"
The Teflon innercore makes Springfield "140" hose assemblies extremely flexible. Long fatigue life.

Hose Assemblies with Reusable Fittings

Springfield "140" Teflon Hose Assemblies are approved for 1500 psi systems. Nominal hose diameter ¼" to ¾". Male pipe and J I C female swivel fittings available from stock.

In which of these applications can you use Titeflex Teflon?

- Acid handling
- Hot waxes and fats
- Liquid adhesives
- Silicone oils
- Chemical processing
- Food and beverage processing
- Steam lines
- Hydrogen peroxide
- Hot lacquers and enamels

Look in the yellow pages of your directory for the Titeflex distributor nearest you, or write direct for Titeflex Springfield "140" Catalog Supplement

TITEFLEX, INC., 508 HENDEE STREET, SPRINGFIELD, MASS.

Long life—Springfield "140" is unaffected by aging. Shelf life is practically unlimited.

*Teflon is a DuPont trademark for its tetrafluoroethylene resin.

. . . MADE RIGHT IN OUR OWN PLANT

Circle 424 on Page 19

STEEL CASTINGS* help build dependability into the modern cargo carrier . . .

..Specifically
UNITCASTINGS!

Transporting America's products by truck-trailer is a gigantic, ever-increasing task—calling for dependable, rugged, long-lasting equipment. This is the reason many manufacturers of over-the-highway carriers specify *foundry engineered UNITCASTINGS* for many component parts.

High quality cast steel affords intricate, one-piece designs . . . offers uniformity and strength for longer life, less maintenance, and more dependable product service.

And . . . *foundry engineered UNITCASTINGS*, produced by superior methods, assure steel castings that are internally sound . . . surfaces that are clean and dimensionally accurate . . . and require minimum finishing. Lower *finished* cost is the *real* advantage of specifying UNITCASTINGS. Write for complete information today!

UNITCAST CORPORATION, Toledo 9, Ohio

In Canada: CANADIAN-UNITCAST STEEL, LTD., Sherbrooke, Quebec

Unitcast

SPECIFICATION STEEL CASTINGS

ference will be held concurrently. Further information can be obtained from Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

June 9-13—

Fourth International Automation Exposition to be held at the Coliseum, New York. Additional information is available from Richard Rimbach Associates Inc., 845 Ridge Ave., Pittsburgh 12, Pa.

June 11-14—

American Society of Mechanical Engineers. U. S. Congress of Theoretical and Applied Mechanics to be held at Brown University, Providence, R. I. Further information is available from ASME headquarters, 29 W. 39th St., New York 18, N. Y.

June 12-14—

National Society of Professional Engineers. Annual Meeting to be held at Chase Hotel and Park-Plaza Hotel, St. Louis. Additional information is available from NSPE headquarters, 2029 K St. N.W., Washington 6, D. C.

June 15-19—

American Society of Mechanical Engineers. Semiannual Meeting to be held at the Hotel Statler, Detroit. Further information is available from society headquarters, 29 W. 39th St., New York 18, N. Y.

June 16-20—

American Society for Engineering Education. 66th Annual Meeting to be held at the University of California, Berkeley, Calif. Further information can be obtained from W. Leighton Collins, University of Illinois, Urbana, Ill.

June 22-25—

American Society of Agricultural Engineers. Annual Meeting to be held at the University of California, Santa Barbara, Calif. Further information can be obtained from society headquarters, 420 Main St., St. Joseph, Mich.

June 22-27—

American Institute of Electrical Engineers. Summer General Meeting to be held at the Statler Hotel,

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Buffalo. Additional information can be obtained from AIEE headquarters, 33 W. 39th St., New York 18, N. Y.

June 22-27—

American Society for Testing Materials. 61st Annual Meeting and Exhibit to be held at the Statler and Sheraton Plaza Hotels, Boston. Additional information can be obtained from ASTM headquarters, 1916 Race St., Philadelphia 3, Pa.

June 23-25—

American Society of Refrigerating Engineers — American Society of Heating and Air Conditioning Engineers joint meeting to be held in Minneapolis. It will be the 54th Annual Meeting of ASRE, whose headquarters will be at the Leamington Hotel. ASHAE will hold a semiannual meeting, with headquarters at the Nicollet Hotel. Separate technical sessions and forums will be held, as well as several joint conferences. Further information is available from ASRE headquarters, 234 Fifth Ave., New York 1, N. Y.

July 8-11—

Institute of the Aeronautical Sciences. National Summer Meeting to be held at the Ambassador Hotel, Los Angeles. Additional information is available from IAS headquarters, 2 E. 64th St., New York 21, N. Y.

"Give me a radius—any radius."

DIAMOND NEWS ABOUT ROLLER CHAIN DRIVES, APPLICATIONS AND NEW PRODUCTS.

Mathews Engineers use stock Diamond Roller Chain for efficient drives on highly specialized machinery!

Mathews automatic and semi-automatic pallet loaders consist of a series of mechanical, electrical and pneumatic components centrally controlled and coordinated by an electrical system.

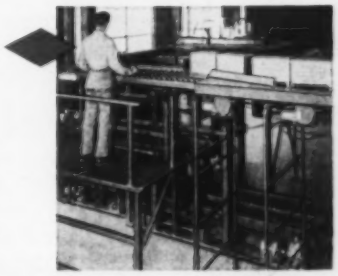
Indicative of sound engineering is the use of standard cataloged Diamond Roller Chain, Conveyor Chain, Attachments and Sprockets for lifting, conveying, power transfer and timing of many operations.

Use of *stock* Diamond Products shortens development time, cuts design costs and lowers production costs. Complete specifications including dimensions, weights, tensile strengths and operating characteristics help both the designer and manufacturer to meet specific requirements.

In addition, specialized machines using cataloged Diamond Products have the added sales value of both superior quality and ready availability of parts to guarantee minimum maintenance and down time.

Controlled Gravity Roller Conveyor

Patented Mathews Conveyor controls the speed at which a heavy load will travel down the conveyor line. Diamond Roller Chain drives the rollers to control speed so that the conveyor offers all the advantages of a gravity conveyor plus the full control of a power conveyor.



General view of Mathews Semi-Automatic Pallet Loader handling cartons of motor oil. Multiple strand Diamond Roller Chains support the pallet and its load.

Discharge side of the Semi-Automatic Pallet Loader. Diamond Roller Chains move loaded pallets out to the roller conveyor. At the same time, Diamond Transfer Chains automatically move an empty pallet into position on the full lift platform.

DIAMOND CHAIN COMPANY, Inc.

A Subsidiary of American Steel Foundries

Dept. 435, 402 Kentucky Ave., Indianapolis 7, Indiana

Offices and Distributors in All Principal Cities

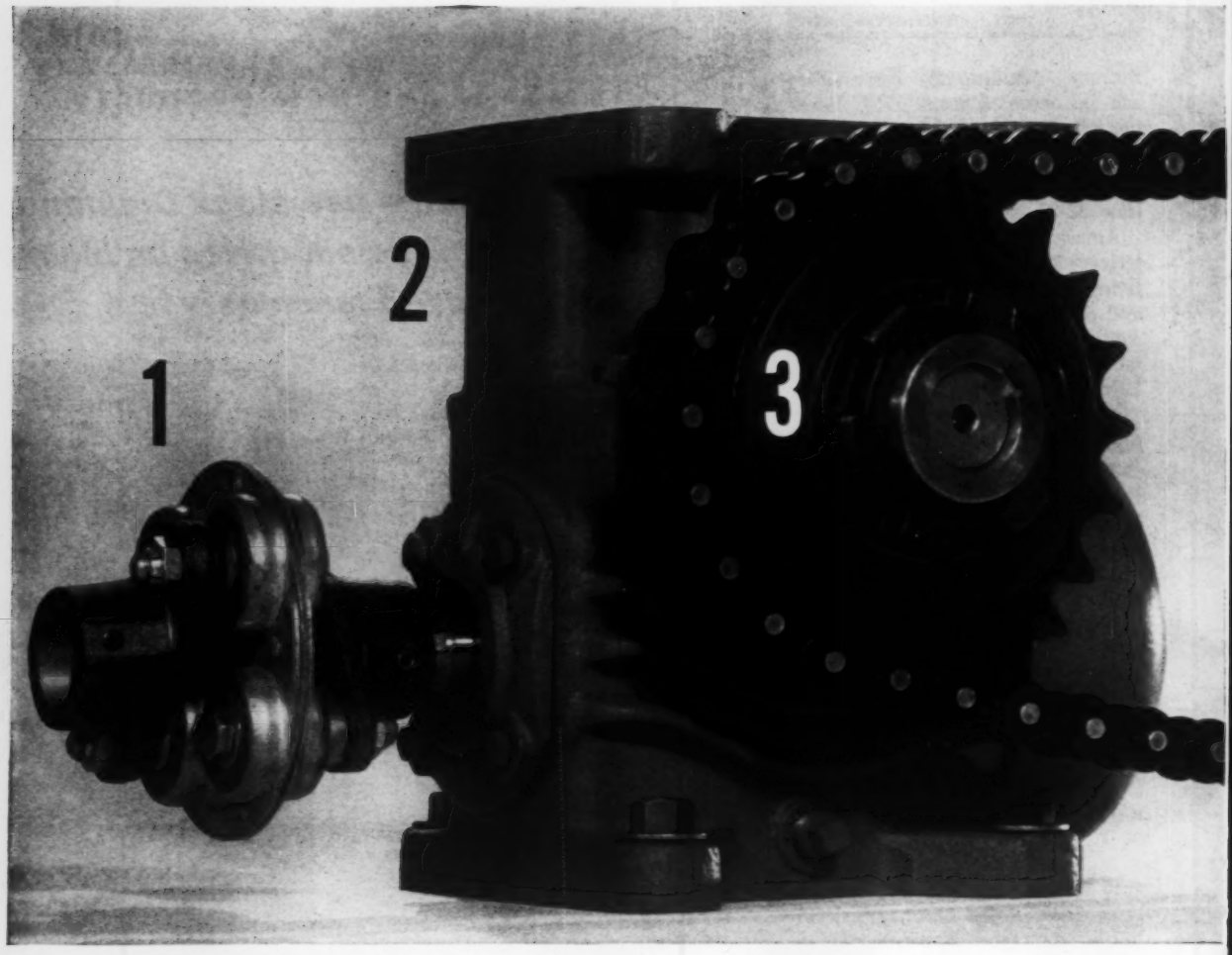
Please refer to the classified section of your local telephone directory under the heading CHAINS *or* CHAINS-ROLLER.

Mathews Controlled Gravity Conveyor system uses Diamond Roller Chains to control the speed at which heavy loads travel down the conveyor.

Write for Catalog 757

DIAMOND ROLLER CHAINS

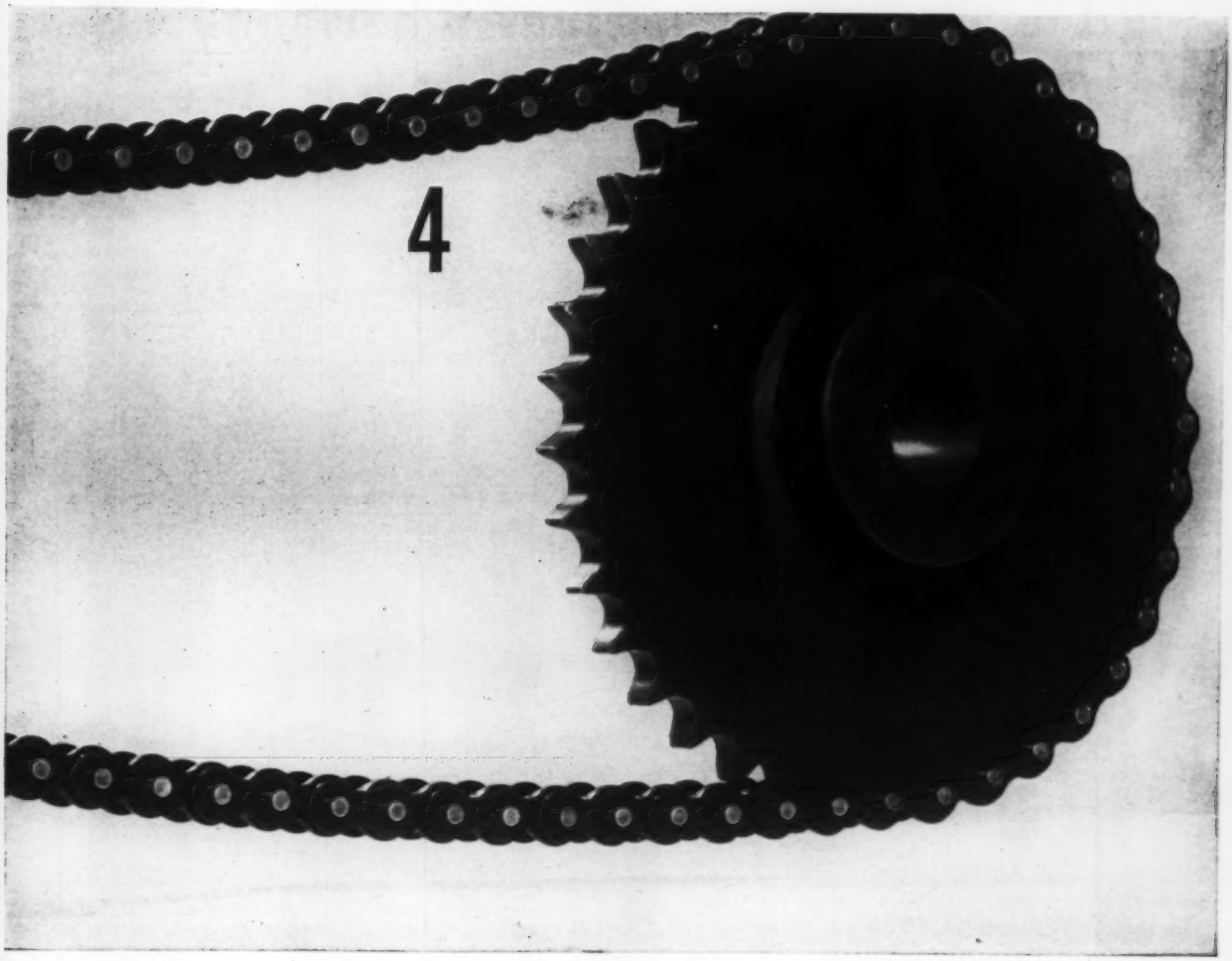
Circle 426 on Page 19



Morse's entry into the speed reducer field means:

Nobody can service your as completely as Morse, all four of these power

1 Couplings and Driveshafts	2 Eberhardt-Denver Speed Reducers	3 Clutches	4 Chain and "Timing" Belt Drives
Morflex	PoweRgear®	Torque Limiter	Roller Chain
Flexible Chain	Worm Gear	Cam	Silent Chain
Radial	Helical	Overcenter	Hy-Vo® Drives
Nylon	Gearmotors	Pullmore	"Timing"® Belt



power transmission needs because only Morse offers transmission components

REMEMBER: The toughest jobs in power transmission come to Morse, because *only Morse* offers one-source service on all four of these basic components . . . and backs them up with technical know-how based on over 60 years' experience solving power transmission problems.

IN POWER TRANSMISSION THE TOUGH JOBS COME TO

MORSE MORSE B-W*

*Trademark

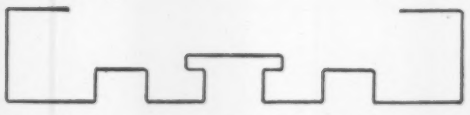
MORSE CHAIN COMPANY, Dept. 6-58, ITHACA, NEW YORK. Export Sales: Borg-Warner International, Chicago 3, Illinois

Circle 427 on Page 19

Why pay for heavy aluminum sections

10,000# x .062 = 2325 LINEAL FEET

when you can buy light gauge Roll Formed shapes



10,000# x .015 = 9250 LINEAL FEET

AND CUT YOUR COST PER LINEAL FOOT

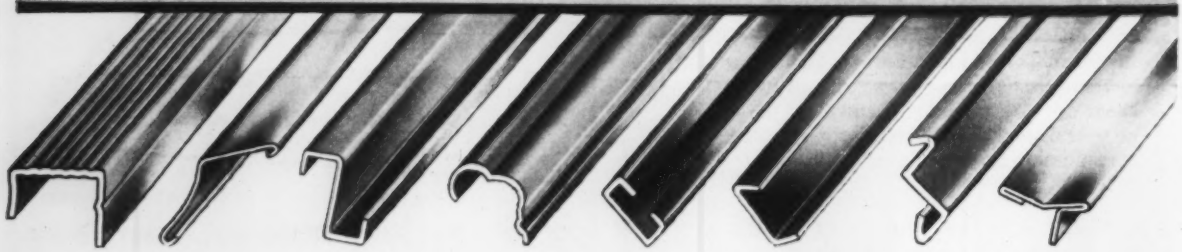
Roll Formed delivers your light gauge aluminum shapes for both functional and decorative use. Here's an opportunity to benefit three ways:

get a lighter weight product,
add greater beauty and utility,
and cut your cost per lineal foot.

It's well worth investigating. Send your prints today. Let us show you the many benefits of Roll Formed's complete service.

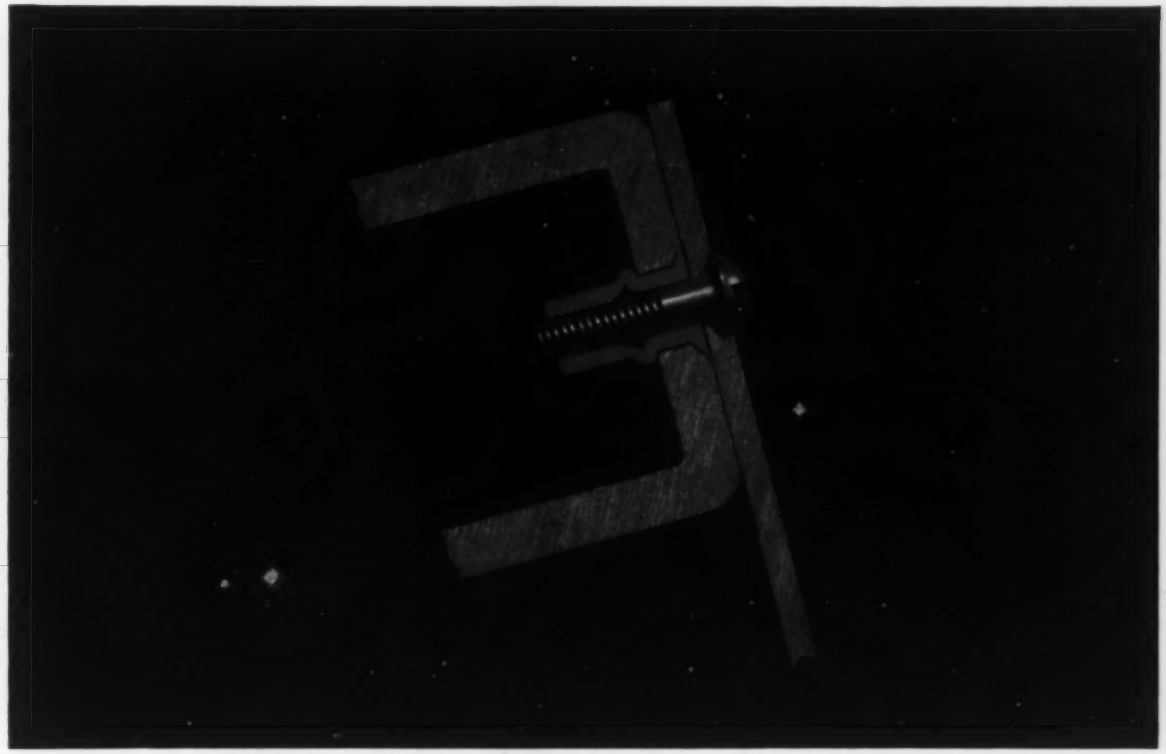
ROLL FORMED PRODUCTS COMPANY

MAIN OFFICE AND PLANT · 3754 OAKWOOD AVE. · YOUNGSTOWN, OHIO

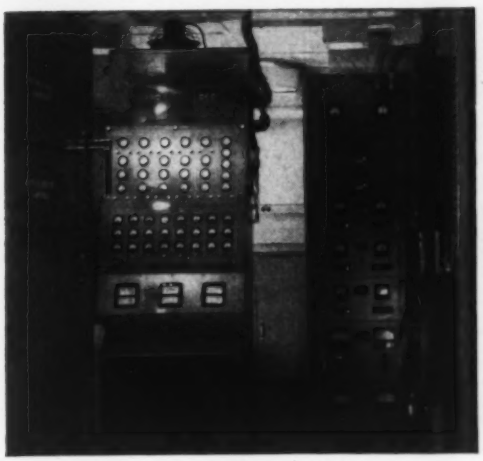


Circle 428 on Page 19

B.F.Goodrich Rivnuts® help fasten electronic "ears" that track orbits of man-made moons



Rivnuts provide sturdy blind nutplates for ultra-sensitive equipment that will receive radio impulses from Vanguard Satellite



During the International Geophysical Year, scientists will launch the first American satellite, the Vanguard. To track its orbit around the earth, "Minitrack" stations in North and South America will receive radio signals from the satellite itself, magnify them with ultra-sensitive receivers, and relay position information to the Vanguard Computing Center in Washington.

The photograph (left) shows the inside of a "Minitrack" station, with the receiver rack in the center. Fastening the face panels on this rack posed a problem for Bendix Radio Division, manufacturers of the equipment. Because the frame is made of square tubular aluminum for greater strength, ordinary nuts and bolts could not do the job.

Bendix found the answer in B.F.Goodrich Rivnuts, which provided sturdy, blind nutplates, easy and economical to install. Whatever you manufacture, from complex electronic equipment to simple sheet metal assemblies, B. F. Goodrich Rivnuts may be the answer to your most puzzling fastening problems.

Write for free Rivnut demonstrator, Dept. MD-58B

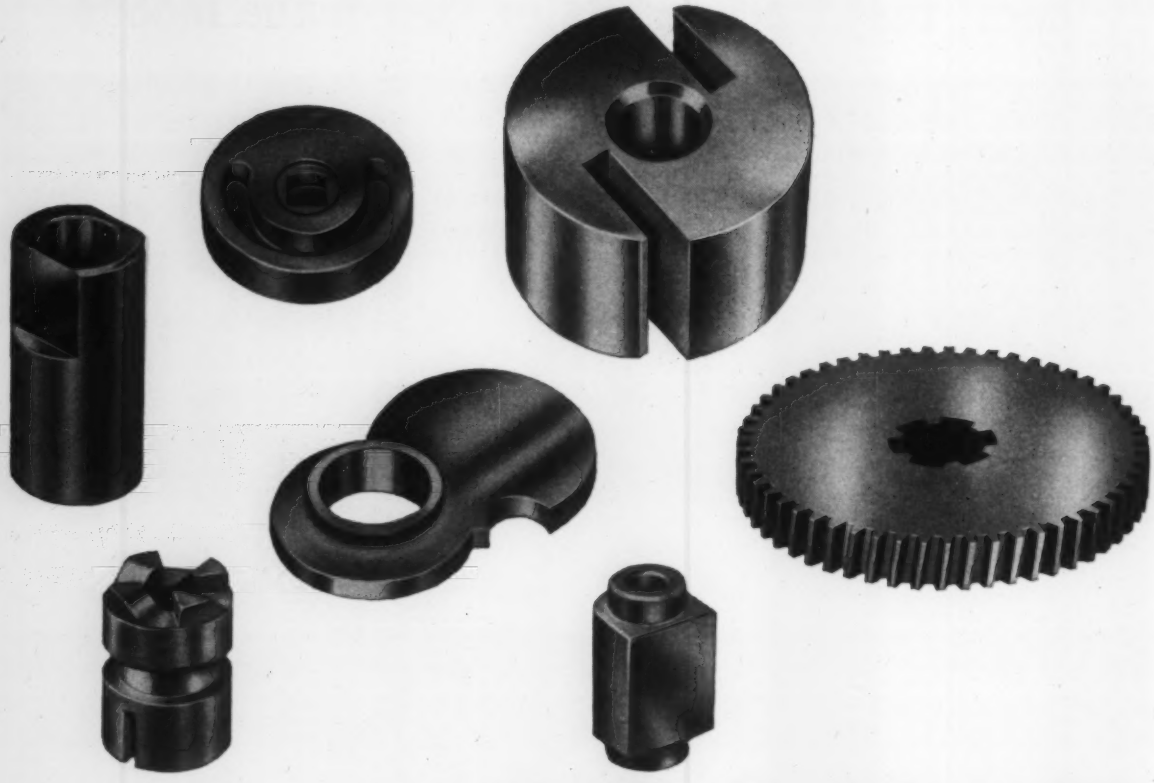
B.F.Goodrich

B.F.Goodrich Aviation Products

a division of The B. F. Goodrich Company, Akron, Ohio

Circle 429 on Page 19

regardless of SHAPE...



economical GRAMIX®

(PRODUCTS OF POWDER METALLURGY)

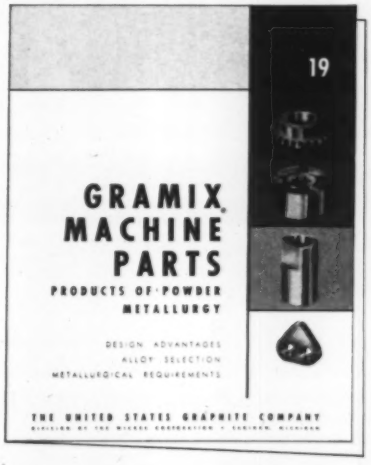
in the exact form to meet your ...ready to install!

Were you to machine the above parts from bar stock, or were you to finish them from rough castings or forgings, the cost would be considerable, due to their complex shapes. However, these parts—and thousands of others of comparable complexity—are produced economically by the GRAMIX process. GRAMIX parts are die-pressed to the exact shape desired, with tolerances as close as .0005", then sintered. Further machining is seldom necessary, though we often perform a coining operation to give the part a burnished, work-hardened surface. GRAMIX parts can be impregnated with various high-grade oils to furnish self-lubrication at wear surfaces. Alloys available include an extensive variety of brass, bronze, and ferrous types, and our manufacturing process allows us to accurately control the density of GRAMIX parts, assuring a uniform structure. There is probably a component in your product that could be improved with GRAMIX sintered metal parts . . . Have you given it consideration?

THE UNITED STATES

GRAPHITAR® CARBON-GRAPHITE • GRAMIX® POWDERED METAL PARTS • MEXICAN® GRAPHITE PRODUCTS • USG® BRUSHES

machine parts can be made design requirements . . .



ENGINEERING BULLETIN No. 19

Product engineers specifying materials will find a wealth of design information in this GRAMIX Machine Parts Bulletin. This material is presented in such concise form that questions are quickly and easily answered. A simple chart indicates which alloys—ferrous and non-ferrous—are suitable for different operating requirements. Working sketches show the various design possibilities—radii, helical teeth, dead-end holes, flanges, multiple shoulders—and how they can be utilized to best advantage. Physical properties are presented, and metallography discussed. In all, you'll find Bulletin 19 an ideally simplified guide to a complex subject . . . write now for your copy. 118

GRAPHITE COMPANY

DIVISION OF THE WICKES CORPORATION, SAGINAW 7, MICHIGAN

Circle 430 on Page 19

Good, Sturdy Blanks all the way through

Fine lot of crane wheels, aren't they? Beautifully machined. They look solid and strong and dependable all the way through. And they're just as sturdy as they look, for they're made from Bethlehem forged-and-rolled blanks.

Bethlehem's unique forging and rolling process imparts soundness, high strength, and excellent grain flow. It makes the machinist's job easier, less costly; the forgings have no hidden flaws to snag and slow the cutting tool.

For making circular steel parts, our forging and rolling process simply can't be surpassed. Bethlehem blanks are widely used in the making of heavy-duty gears, crane and sheave wheels, turbine rotors, flywheels, pipe flanges, and many other circular products. Available in either carbon or alloy steel, they can be furnished in a wide choice of sections and in sizes from 10 to 46 in. OD.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by
Bethlehem Pacific Coast Steel Corporation
Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Circle 431 on Page 19

a growing variety of Quality Fasteners

1. Alloy Steel Engine Bolt
2. Alloy Steel Engine Stud
3. Alloy Steel Engine Bolt
4. Alloy Steel Airframe Bolt
5. Super Alloy Engine Bolt
6. Alloy Steel Engine Bolt
7. Stainless Steel Engine Bolt
8. Stainless Steel Engine Bolt
9. Alloy Steel Airframe Bolt
10. Stainless Steel Engine Bolt
11. Alloy Steel Engine Bolt
12. Stainless Steel Engine Pin
13. Stainless Steel Engine Stud
14. Alloy Steel Airframe Bolt
15. Stainless Steel Engine Bolt
16. Stainless Steel Airframe Bolt
17. Stainless Steel Hi-Shear Rivet
18. Alloy Steel Hi-Torque Bolt
19. Cabuckle
20. Titanium Lockbolt
21. Titanium Hi-Torque Bolt
22. Fastbolt & Fastnut
23. Titanium Lockbolt
24. Titanium Hi-Shear Rivet
25. Std. Hex Head Bolt
26. Std. Internal Wrenching Bolt
27. Std. Internal Wrenching Bolt
28. Std. Hex Head Bolt
29. Std. Flush-Head Bolt
30. Std. Flush-Head Bolt
31. Std. Hex Head Bolt
32. Std. Hex Head Bolt

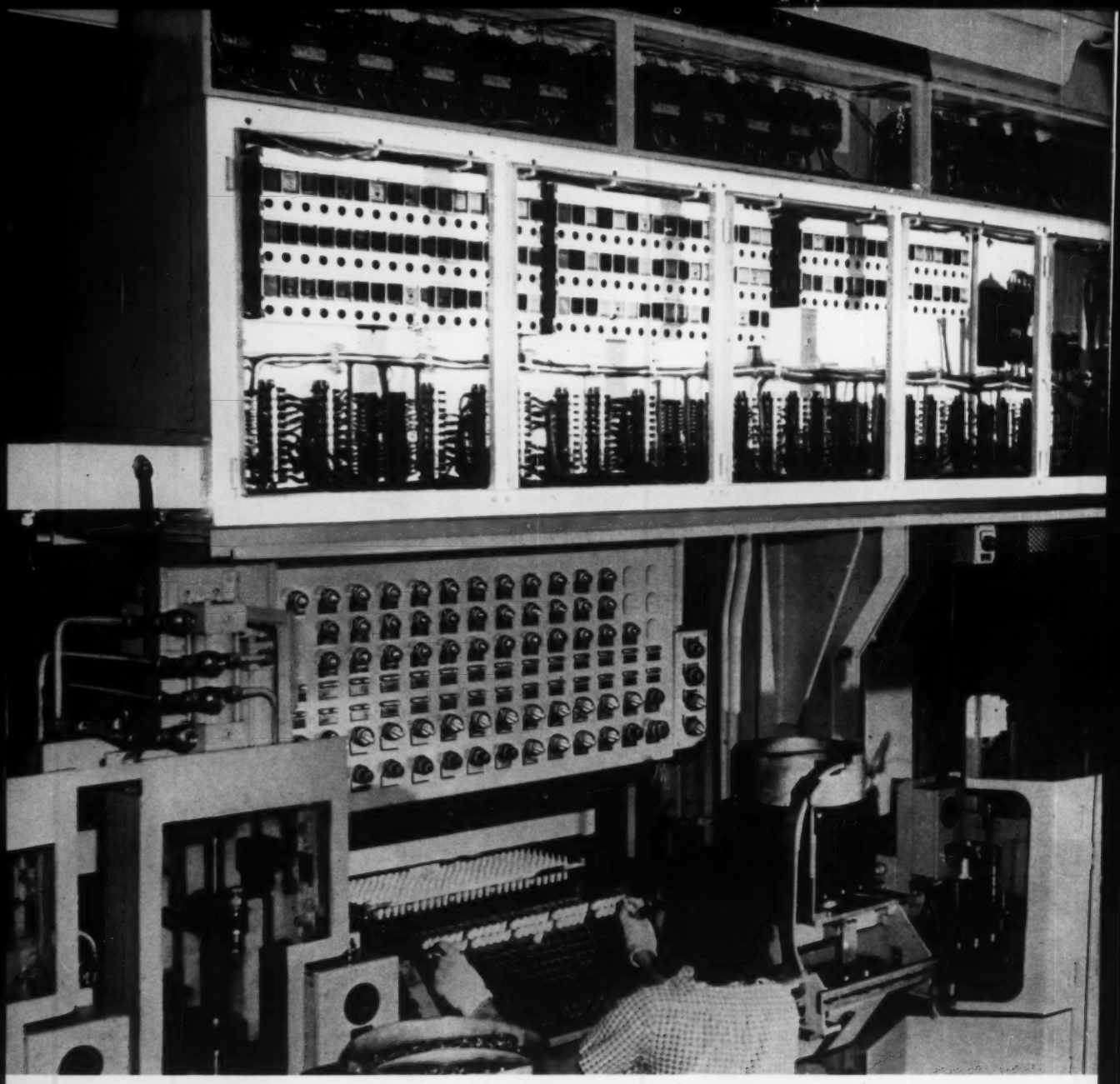
IN THE FASTENING FIELD Voi-Shan has the ultimate in facilities, skill, and experience. This is your assurance of consistent perfection in every type of fastener.

VOI-SHAN MANUFACTURING COMPANY

A division of PHEOLL MANUFACTURING COMPANY
8463 Higuera Street, Culver City, California

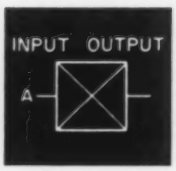
Circle 432 on Page 19

Circle 433 on Page 19→

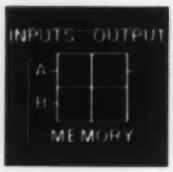


FIVE BASIC CONTROL FUNCTIONS OF G-E STATIC CONTROL "LOGIC ELEMENTS"

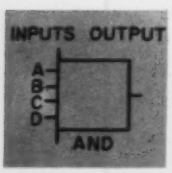
G-E static control "logic elements" correspond to relays in conventional control. They convert a combination of inputs into a single output by controlling the impedance of an output coil. Any static control panel* consists of proper combination and sequencing of these five basic logic control elements:



THE "NOT" ELEMENT produces an output only when input A is *not* present. Conversely, when input A *is* present, the "not" element will *not* produce an output.

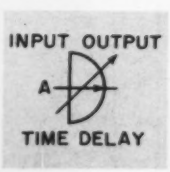


"MEMORY ELEMENT" maintains its output after momentary A input, *until* a momentary B input stops the output. Another A input is necessary to renew the output.



THE "AND" ELEMENT will deliver an output *only* when all inputs (A, B, C, and D) are present. Three inputs or less *cannot* cause the element to deliver an output.

THE "OR" ELEMENT will produce an output when input A *or* B *or* C *or any* combination of inputs is present. One, two or three inputs will produce an output.



THE "TIME DELAY" ELEMENT will produce an output *after* a pre-set time period following an A input. Output then continues until input A is removed from circuit.

*The complete static control system includes power supply, amplifiers, logic elements, and panel mounting components.

General Electric's Proved...

Static Control Components Reduce Machine Downtime

PLUG-IN COMPONENTS WITHOUT MOVING PARTS GIVE REAL DESIGN FLEXIBILITY, SPEED ASSEMBLY

Static control is now a *proved* method of control that's easy to adapt to your machines. It's ideal wherever long, dependable operation is vital, and where shutdowns cannot be tolerated, because static control life is *independent of the number of operations.*

G-E static control components simplify panel design

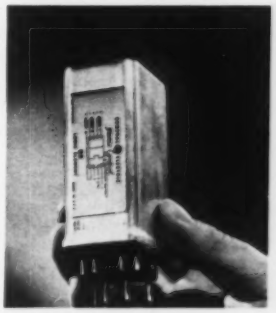
Five basic General Electric logic functions can be combined to perform your control operations. All *you* have to do is translate the operation of your machine into logic functions — then combine G-E logic elements into the proper sequence.

Panel assembly is fast and easy

General Electric logic elements are only 4¼" high, weigh less than 5 ounces. Parts are encapsulated in a resilient compound and encased in aluminum. Each element is color-coded as to function, and plugs into a base receptacle which is connected to a printed circuit. You need do only a minimum of wiring.

A typical user reports

A major automotive manufacturer expects the static control panel with G-E components on the spark plug assembly machine shown at left to significantly increase production because of reduced downtime. The electrical supervisor of the manufacturing development section says: "Our first static control panel was on a different high-speed assembly machine — where maintenance could be a real problem. With Static Control, we haven't had an electrical control failure of any kind in a year. We now have three panels in use, and are designing panels for others where maintenance of conventional control has posed a problem. We chose G-E components because of the simplicity of the system, easier wiring, and their practically fail-safe operation."

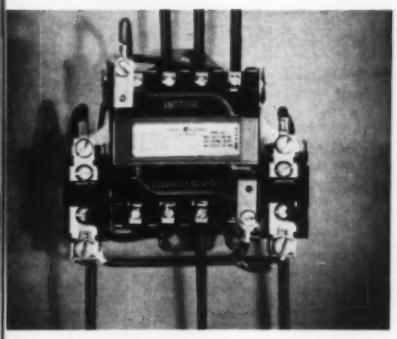


Static Control Logic Element

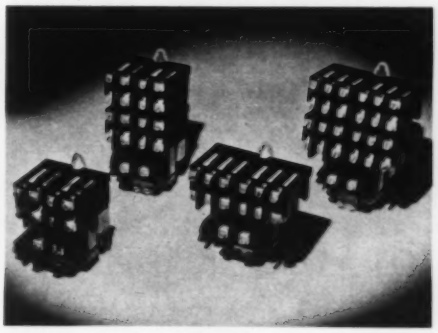
Static Control is available today in simple, easy-to-use components that are proved in service. If you haven't yet investigated G-E static control components, why not do so right now? Just call your G-E Apparatus Sales Office, or write Sect. 731-14, Schenectady, N. Y., for bulletin GEA-6578.

General-Purpose Control Dept., Bloomington, Ill.

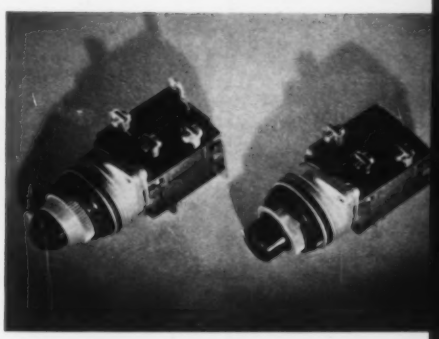
GENERAL ELECTRIC



NEW 100-LINE MAGNETIC STARTERS, Sizes 0 and 1, are 42% smaller. They save valuable panel space, use 47% smaller control transformers, and they feature straight-through wiring.

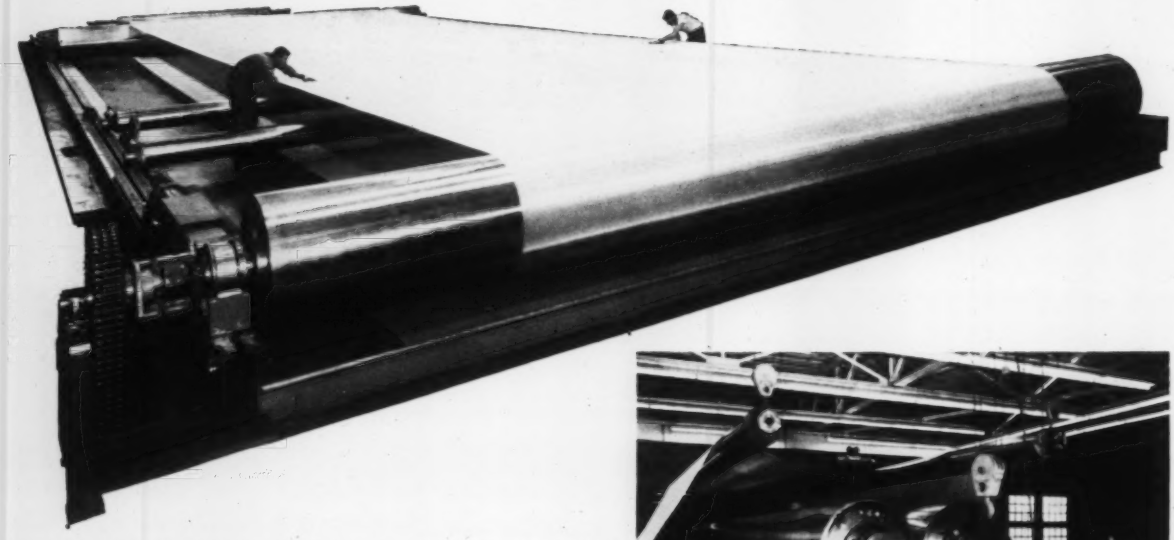


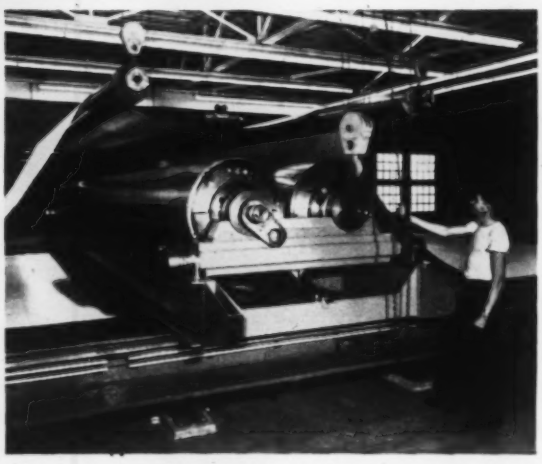
MACHINE TOOL RELAYS have front-connected terminals and are easy-to-wire from four directions. They're available with 2 through 12-poles, and in both standard and latched-in forms. Ratings: 110 to 600 volts, 60 cycles.



PUSH BUTTON UNITS: The G-E push to test unit provides a fast, easy check for burned-out bulb and the new G-E illuminated push button unit reduces panel space by 50%.

In specialized applications...
ACIPCO *CENTRIFUGALLY SPUN* STEEL TUBES





Appleton Wire Works, Inc., manufactures high quality fourdrinier wires for paper making machines. These fine-mesh wires are woven in widths up to 340 inches and lengths over 180 feet.

At its Montgomery, Alabama, plant, Appleton Wire Works, Inc. uses ACIPCO steel tubes— centrifugally spun and polished at Acipco—as stretch rolls on the huge finishing table. These 35.625" OD, 410" long rolls must be both dimensionally stable and balanced and must have a polished surface which will not affect the delicate woven wire surface mechanically or chemically.

Here is another example of Acipco versatility. If your application requires heavy wall steel or alloy iron tubes with special physical, chemical or metallurgical properties "built-in," Acipco can serve you. Investigate Acipco's complete "one source—from start to finish" facilities. A call or letter will bring full information on Acipco centrifugally spun tube applications in your field.

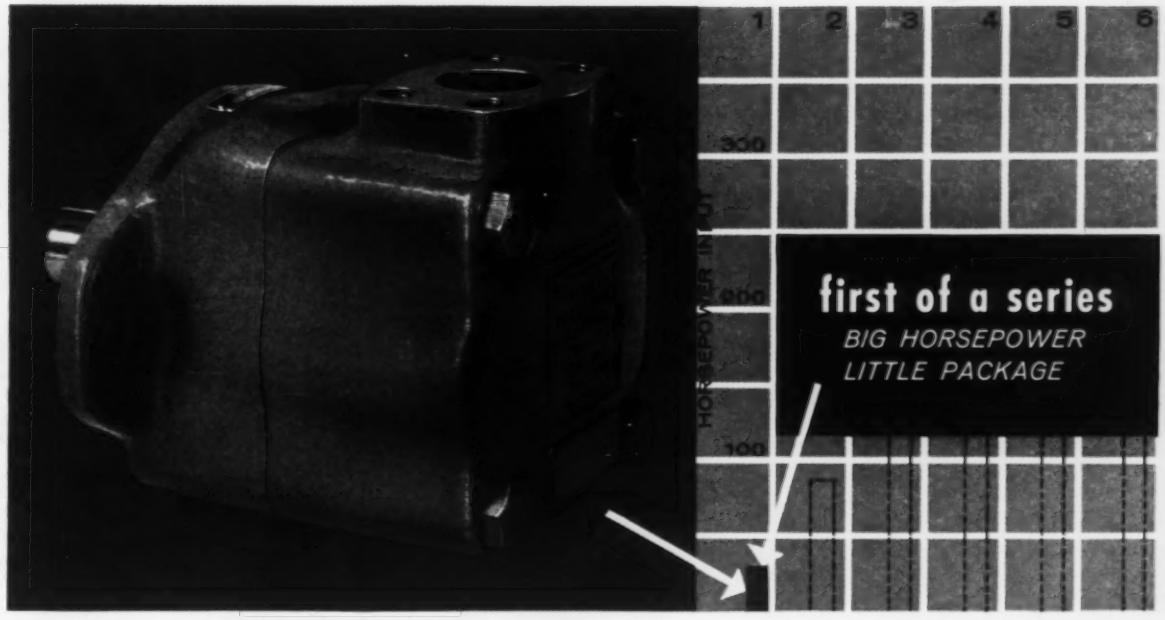
VERSATILE ACIPCO CENTRIFUGALLY SPUN STEEL TUBES

Size Range: Lengths up to 410" to meet modern machinery requirements have been produced. OD's from 2.25" to 50"; wall thicknesses from .25" to 4".

Analyses: All alloy grades in steel and cast iron, including heat and corrosion resistant stainless steel, plain carbon steel and special non-standard analyses.

Furnished: As cast, rough machined, or finished machined, including honing. Complete welding and machine shop facilities for fabrication.

SPECIAL PRODUCTS DIVISION
AMERICAN CAST IRON PIPE CO.
BIRMINGHAM 2, ALABAMA



NEW VICKERS® high performance vane pump

• high speed • high pressure • high efficiency • high service life

NEW COMPACT DESIGN . . . more than twice the horsepower of previous pumps in the same package size.

NEW VANE CONSTRUCTION . . . positive vane tracking at all speeds assures efficient operation at increased speeds and pressures.

NEW SIZES not previously available . . . answers mobile equipment designers' need for greater hydraulic horsepower in limited space.

NEW PARTS INTERCHANGEABILITY . . . many common parts for single and double pumps (two pumps on the same shaft in one envelope). Lessens inventory requirements.

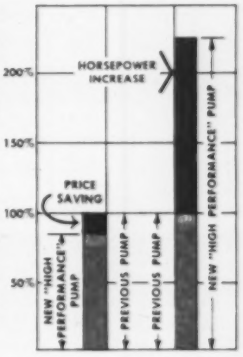
NEW 4-BOLT SAE FLANGE CONNECTIONS . . . will also accommodate user's 2-bolt flanges of the proper design.

NEW 2-BOLT MOUNTING (SAE 1959 STD.).

NEW REPLACEABLE PUMPING CARTRIDGE . . . all wearing parts of pump are incorporated in one replaceable cartridge. Easy field replacement without removing pump from its mount. Cartridges available in kit form.

MORE HORSEPOWER PER DOLLAR. The graph at the right makes a revealing comparison between this new pump and a previous pump of the same rated delivery. The new Vickers "High Performance" pump provides more than *twice the horsepower* at *less cost* while shrinking package size from 200 to 112 cubic inches.

The complete line of "High Performance" pumps (both single and double) is being readied for release. Size range will accommodate your largest requirements. This first model of the series is available in three ring capacities; 12 gpm, 14 gpm, and 17 gpm as shown in table below.



Model Number	Delivery-GPM 1200 RPM 100 PSI	Delivery-GPM 2000 RPM 2000 PSI	Input Horsepower @ 2000 RPM 2000 PSI	Package Size†	Weight
2V12A-**10	11.8	17.8	25.5	L. 5⅞" W. 4⅝" H. 5¾"	26 Lb.
2V14A-**10	13.6	20.4	29.0		
2V17A-**10	16.6	25.2	36.0		

†Exclusive of Shaft Extension and Mounting Lobes

8050

Write for new illustrated Bulletin No. M5108 for further details and performance characteristics.

VICKERS INCORPORATED
DIVISION OF SPERRY RAND CORPORATION
Mobile Hydraulics Division
ADMINISTRATIVE and ENGINEERING CENTER
Department 1430 • Detroit 32, Michigan

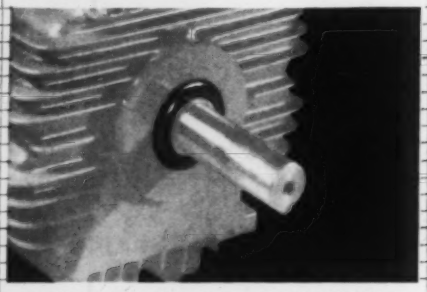
Application Engineering Offices: • ATLANTA • CHICAGO • CINCINNATI CLEVELAND • DETROIT • GRAND RAPIDS • HOUSTON • LOS ANGELES AREA (El Segundo) • MINNEAPOLIS • NEW YORK AREA (Springfield, N.J.) PHILADELPHIA AREA (Media) • PITTSBURGH AREA (Mt. Lebanon) PORTLAND, ORE. • ROCHESTER • SAN FRANCISCO AREA (Berkeley) • SEATTLE • ST. LOUIS • TULSA
FACTORIES ALSO IN AUSTRALIA, ENGLAND, GERMANY AND JAPAN IN CANADA: Vickers-Sperry of Canada, Ltd., Toronto, Montreal and Vancouver

ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921

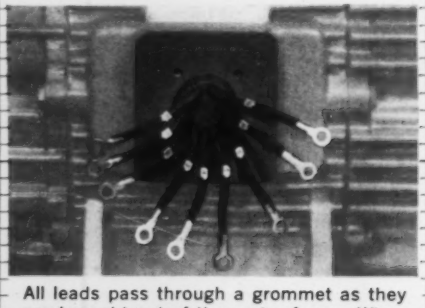
Circle 435 on Page 19

ELLIOTT C-W SEALEDPOWER

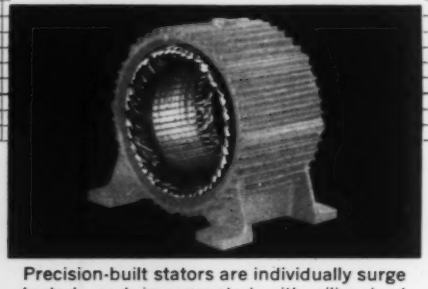
Sturdy external fan has a split hub both keyed to the shaft. No chance of slippage or loosening.



A slinger on the motor shaft effectively guards against the entrance of moisture and foreign material. Slinger is recessed into the bearing bracket to provide a long, labyrinth-type seal.



All leads pass through a grommet as they are brought out of the motor frame. When conduit box is mounted in position, the grommet is tightly compressed, providing a snug seal at this vulnerable area.



Precision-built stators are individually surge tested, and impregnated with siliconized varnish, for improved heat stability and heat resistance.

. . . designed for the dirty jobs

Elliott C-W Sealedpower motors can safely be installed outdoors, or in dusty, moist and corrosive atmospheres. Internal parts are thoroughly protected from the environment. Many users have standardized on this type of motor for all applications because they find that the total cost—first cost plus maintenance—is less for totally-enclosed motors than for conventional enclosures!

This popular, dependable group of motors is part of the Elliott C-W line, which includes also standard Dripproof-protected and Explosion-proof designs.

The original C-W fin-cooled, self-cleaning design which provides more cooling area—no internal passages to clog.

ELLIOTT Company

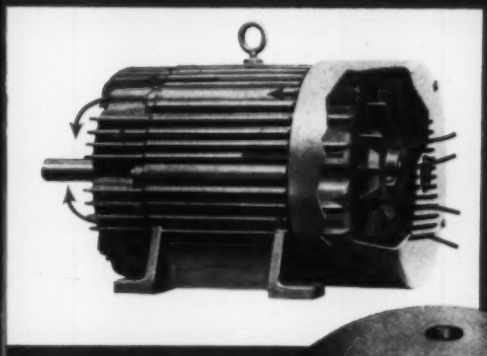
CROCKER-WHEELER PLANT, Jeannette, Pennsylvania

Write for Bulletin PB 6000-6, which describes in detail the features which make Elliott C-W motors outstanding.

WB-2

Circle 436 on Page 19

ENCLOSED MOTORS



Where PRECISION and QUALITY count, TOPP offers POWER SUPPLIES of advanced design for Airborne or Ground Applications incorporating Short Circuit Protection, Dynamic Regulation and reliable Miniaturization. Built to withstand extremes of Vibration, Shock, and other Environmental conditions.

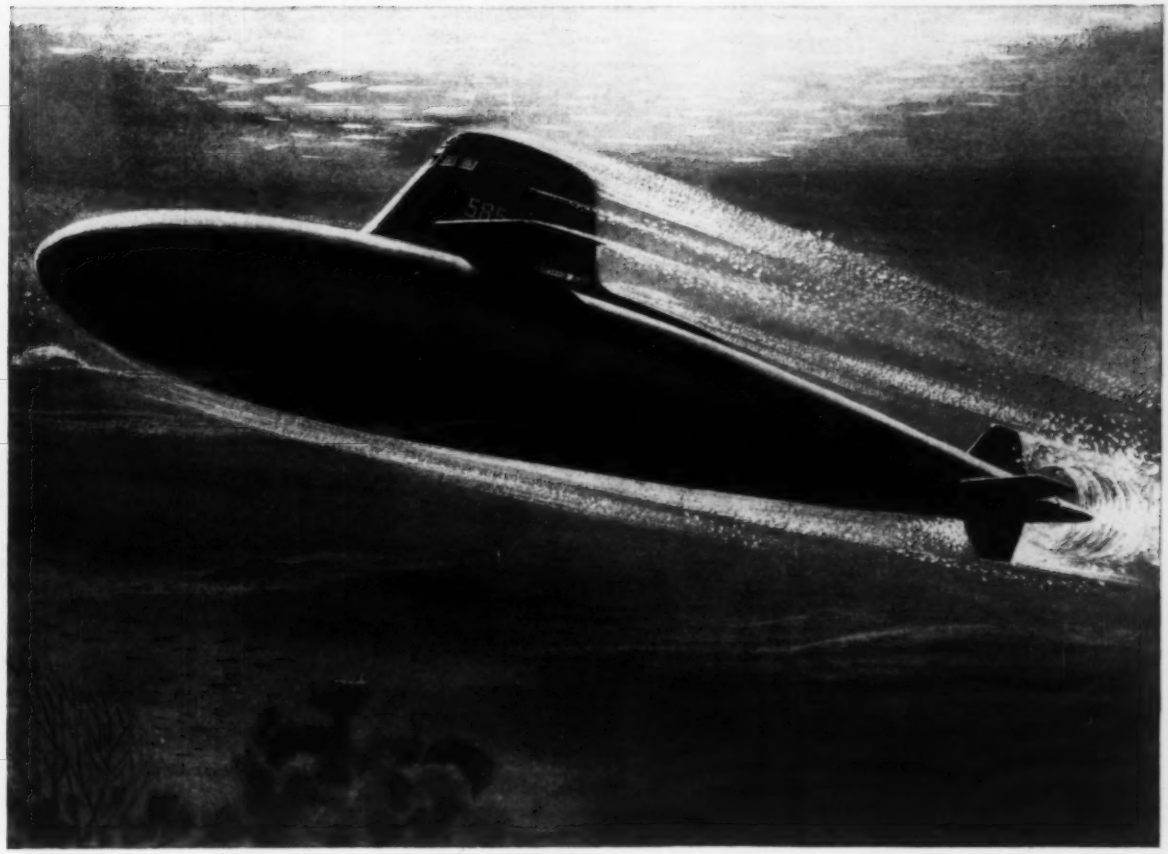
Present major applications include installations in the ATLAS and TITAN ICBMs, as multi-output dc to dc telemeter and command receiver power supplies.

AVIONICS DIVISION

TOPP
MANUFACTURING COMPANY
5221 TO2ND ST., LOS ANGELES 45, CALIFORNIA

A DIVISION OF TOPP INDUSTRIES, INC.

Circle 437 on Page 19



Sandusky cylinders help the Skipjack CRUISE, DIVE, STEER, BREATHE and FIGHT!

Centrifugally cast cylinders by Sandusky play vital roles in the U. S. Navy's newest atomic-powered submarine, No. 585 *Skipjack*, as components of the nuclear propulsion system, the steering and diving systems, the torpedo firing mechanism, and radar and induction mast assemblies.

The *Skipjack* is the prototype of a new series of seven submarines all with blimp-shaped hulls for greater underwater speed. Her design and materials specifications were laid down by the U. S. Navy and her builder, The Electric Boat Division of General Dynamics Corporation, who chose Sandusky Centrifugal Castings to do more than ten jobs in structural, mechanical, pneumatic, and hydraulic applications.

All of these components – centrifugally cast of heat and corrosion-resistant stainless steels, high-strength carbon steels, Monels, and bronzes–provided the *Skipjack's* designers with the required mechanical and physical properties at the lowest cost.

You, too, may find a ready solution to your cylindrical problems in Sandusky Centrifugal Castings. We invite your inquiries.

Sandusky cylinders are cast and machined in this range:

From 7" to 54" O.D.

Up to 33 ft. in length (depending on diameter)

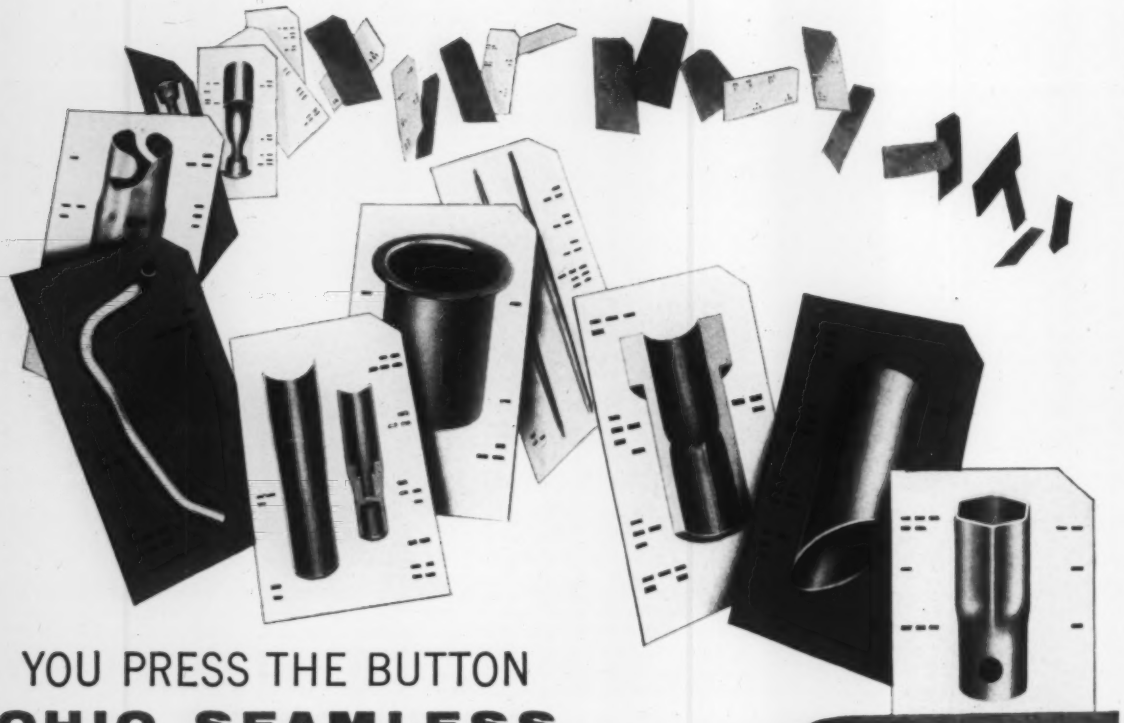
Light or heavy-walled

In a variety of alloys including Stainless, Carbon, Low Alloy Steels. A full range of Copper-Base, Nickel-Base Alloys.

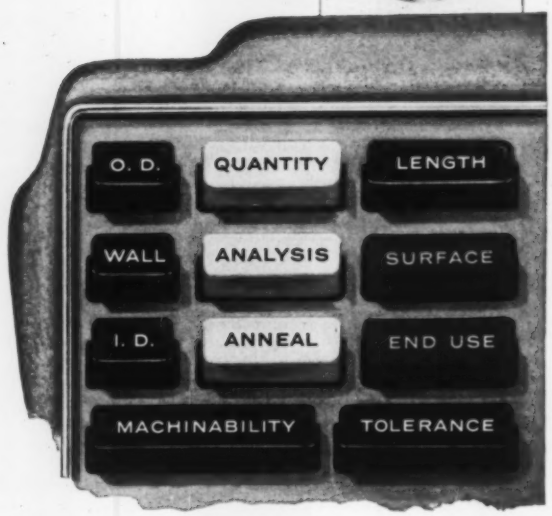
SANDUSKY CENTRIFUGAL CASTINGS
FOUNDRY & MACHINE CO.
SANDUSKY, OHIO

Circle 438 on Page 19

When you buy from Ohio Seamless



YOU PRESS THE BUTTON
OHIO SEAMLESS
DOES THE REST



Buying steel tubing from Ohio Seamless doesn't cost—it *pays*. Our minimum quantities are generally smaller than you may realize . . . often as small as 100 to 150 feet, in certain seamless grades and sizes.

When you buy from us, you're dealing with tubing *experts* . . . men who can recommend the *exact* Ostuco Tubing to suit your product and processes. There's no compromise on analysis, size, anneal, etc.

Advantages of buying from Ohio Seamless multiply, the closer you examine them. Our single-source service eliminates headaches of interplant shipments . . . possible errors . . . multiple purchase orders and invoices. Ohio Seamless keeps your production lines humming because you get *precisely what you want.*

For proof, contact our nearest sales office or the plant at *Shelby, Ohio—Birthplace of the Seamless Steel Tube Industry in America.*

AA-7118

SALES OFFICES: BIRMINGHAM • CHARLOTTE • CHICAGO (Oak Park) CLEVELAND • DAYTON • DENVER • DETROIT (Ferndale) • HOUSTON LOS ANGELES (Lynwood) • MOLINE • NEW YORK • NORTH KANSAS CITY PHILADELPHIA (Wynnewood) • PITTSBURGH • RICHMOND • ROCHESTER ST. LOUIS • ST. PAUL • ST. PETERSBURG • SALT LAKE CITY • SEATTLE TULSA • WICHITA

CANADA: RAILWAY & POWER ENGR. CORP., LTD.

EXPORT: COPPERWELD STEEL INTERNATIONAL COMPANY
225 Broadway, New York 7, New York

FIFTY YEARS
OSTUCO TUBING
1908 1958

OHIO SEAMLESS TUBE DIVISION
of Copperweld Steel Company SHELBY, OHIO

Seamless and Electric Resistance Welded Steel Tubing • Fabricating and Forging

PRODUCT-DESIGN MEMOS FROM DUREZ

Heavy-duty parts
Making epoxies flame-resistant
Metallized phenolics

Chrysler Corporation

Rugged

Got a job that's "too tough for phenolics"?

You might never think of phenolic for a part like this Chrysler-engineered automotive oil-pump gear—subject to wear, heat, friction, constant oil immersion.

But you'd be reckoning without the ruggedness of a new phenolic, *Durez 16771*.

Parts molded from this glass-fiber-filled compound have a flexural strength of 20,000 psi, compressive strength of 16,500 psi. Their tensile strength is 7,000 psi. Modulus of elasticity in tension is 3.0×10^6 psi. What's more, the heat distortion point of these parts is up around 600° F.

Payoff • These properties, plus excellent resistance to oil, water, and acid, made Durez 16771 appear to have some of the properties needed for the Chrysler oil-pump gear. After extensive experimenting and testing, Chrysler engineers developed the plastic gear to replace the usual metal part.

Results: *new gears of Durez 16771 outwear metal gears nearly 3 to 1—show no performance-affecting wear after 200,000 miles; save about two-thirds of the cost of metal gears; run more quietly.*

For a data sheet describing this high-strength phenolic, check opposite "16771" on the coupon.

How to make epoxies resist flame

Your epoxy laminates and castings will shrug off heat, moisture—even fire—if you cure them with a new Durez product called HET® Anhydride.

In the picture that follows, the laminate cured with a conventional hardener ignites in less than 30 seconds and burns to destruction in about 3 minutes. Exposed to a similar flame source for the same time, a HET-cured laminate snuffs itself out as soon as the flame source is removed.

This leads to some interesting possibilities. For instance, you can now make glass-reinforced laminates that keep practically all their flexural strength, *even when heated within the 300-350° F range.*

You can make potting resins that retain room-temperature electrical properties at high humidities *and at temperatures above 300° F*—and won't feed a fire.

For easier casting or wet layup, you need not handle HET Anhydride hot. You can mix it with another anhydride to form a curing system that *stays liquid at room temperature.* Toxicity is very low.

If you'd like complete information on HET Anhydride, methods of use, and properties of cured resins, check the coupon for Bulletins 19 and 43.

Bright idea

Next time you want to put a bright reflective surface on a part, think of *metallized phenolic.* It may save you a costly production step.

American Optical Company

For instance, this housing for a microscope lamp requires a mirror to focus the light.

To sidestep the cost of a custom-made mirror, the housing is molded of Durez phenolic. Then an aluminum mirror is deposited right on the plastic by vacuum evaporation.

This is easy to do with the Durez compound chosen for this part. It provides a good hard surface for metallizing. It incorporates other wanted properties: high impact strength and low thermal conductivity.

You're on sure ground when you base bright ideas like this on phenolics. They give you a bigger choice of controlled properties than any other material in their class. You can select the right balance from *more than 150 Durez compounds.*

To take a fresh look at today's phenolics, just check the coupon for a new four-page bulletin describing some typical Durez molding compounds and what you can do with them.

For more information on Durez materials mentioned above, check here:

- ☐ High-impact Durez 16771
- ☐ HET Anhydride—Bulletins 19 and 43
- ☐ Phenolic molding compounds—descriptive bulletin

Clip and mail to us with your name, title, company address. *(When requesting samples, please use business letterhead.)*

DUREZ® HOOKER CHEMICALS PLASTICS

PLASTICS DIVISION
HOOKER ELECTROCHEMICAL COMPANY
505 Walck Road, North Tonawanda, N. Y.

Circle 440 on Page 19

How you get more than just a motor

You get true design flexibility with

Suppose you have a particularly tough design problem—one that requires a specific motor to give the best results. You don't want to take a chance on not getting the right motor for the job.

This is where Century Electric's complete line of a-c and d-c motors, 1/20 to 400 hp, can be of help to you. You have a complete variety of motors from which to choose. Makes it lots simpler than shopping around to find what you need.

For help on your particular design problem, contact your Century Electric sales engineer. He has the know-how that comes from applying, engineering and thinking motors and nothing but motors day in and day out. If he can't give you on-the-spot

Century Electric's complete line of motors

answers, he has an experienced engineering staff backing him that can come up with quick, dependable answers to your problem.

This is why you get *more* than a motor when you take your motor and generator design problems to Century Electric. You get a quality product backed by know-how. You can call on men who want to help you get the right motor for your job. For more information, contact your local Century Electric Sales Office or Authorized Distributor.

CENTURY ELECTRIC COMPANY

St. Louis 3, Missouri *Offices and Stock Points in Principal Cities*

Century

58-5

Circle 441 on Page 19

ESCO CENTRIFUGAL CASTINGS KEEP

MACH 17 IN A TUBE!

Tremendous pressures and temperatures are generated in this shock tube at Lockheed Aircraft Corp., to simulate conditions encountered by a long-range ballistic missile re-entering the earth's atmosphere. High pressure gas triggers shock waves which travel 17 times the speed of sound. Instantaneous temperatures range above 15,000 degrees F.

The 44-foot long tube is an assembly of *ESCO* heavy-wall Spuncast® castings hydrostatically tested at 10,000 PSI. It is typical of the many exacting casting jobs that wind up at *ESCO*.

Simplify your design problems by calling *ESCO* for special alloy steel Spuncast pipe, standard heavy wall fittings, and special design fittings and valves.

ESCO®

ELECTRIC STEEL FOUNDRY COMPANY

2183 N. W. 25TH AVE. • PORTLAND 10, OREGON

MFG. PLANTS AT PORTLAND, ORE. AND DANVILLE, ILL.

Offices in Most Principal Cities

ESCO INTERNATIONAL, NEW YORK, N. Y.

IN CANADA ESCO LIMITED

Circle 442 on Page 19

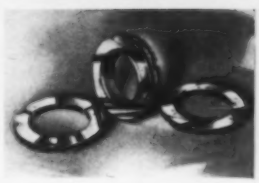
NEW "MIRROR-FINISH" ON GARLOCK METAL PACKINGS

...provides positive sealing at no extra cost

Now all Garlock Metal Scraper and Packing Rings have a surface finish of 10 micro-inches or less! And flatness of the rings is measurable in light bands; which means a more positive seal between ring and groove. This exclusive Garlock advantage has been made possible through improved manufacturing technique and is offered to you without additional cost.

Garlock Metal Packings with the exclusive "Mirror-Finish" are another part of the famous "Garlock 2,000" . . . two thousand styles of packings, gaskets, and seals for every need. The only complete line. That's why you get unbiased recommendations from your Garlock representative. Call him or write for Metal Packings Folder 3888-9.

Floating Metal Packing Sets are designed for use on reciprocating rods of air and gas compressors; steam and gas engines. Available in either solid cup or split-case design. Solid cup design (illustrated at right) withstands pressures to 30,000 psi.



Garlock Metal Packing Rings of graphitic cast iron, bronze, carbon, bakelite and babbit are precision made to exact specifications of size and finish assuring maximum efficiency.

THE GARLOCK PACKING COMPANY, Palmyra, New York

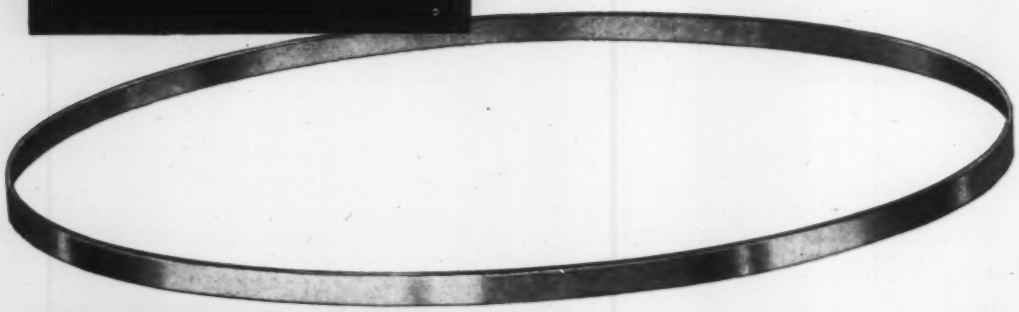
For Prompt Service, contact one of our 30 sales offices and warehouses throughout the U.S. and Canada.

GARLOCK

Packings, Gaskets, Oil Seals, Mechanical Seals, Molded and Extruded Rubber, Plastic Products

Circle 443 on Page 19

Precision Rings with little or no machining



Today you can purchase precision flash butt-welded rings that require little or no machining to meet your specifications. Made from bar stock of finished gauge, they can be produced to meet the same tolerances as conventionally machined rings. Cost of production and materials of some rings has been reduced as much as 60%. Sizes and materials at present are limited to those bar stocks which can be furnished to precise finished dimensions. However, persistent efforts of American Welding engineers and the producers of finished bars give promise of a widening range of sizes and metals that can be manufactured by precision forming and welding.

This is another example of why you should call American Welding first — if the problem is circular and of metal.

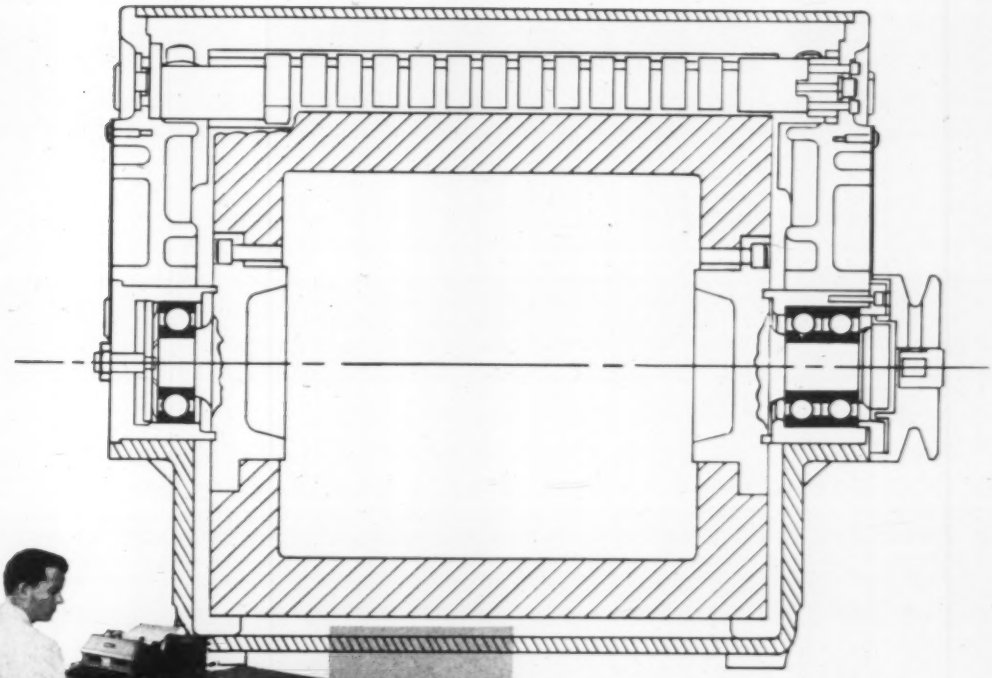
New Products Catalog

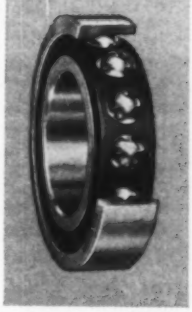
Write today for 20-page catalog of circular products which American Welding can form, weld and machine for you.

AMERICAN WELDING

THE AMERICAN WELDING & MANUFACTURING CO.
130 DIETZ ROAD • WARREN, OHIO

Circle 444 on Page 19





The new Royal Precision LGP-30 is a serial, single address, fixed point binary, stored program digital computer featuring simplified design and ease of operation. The unit is designed to make computer use economical and simple enough for more widespread application.

Fafnir Super-Precision Type Ball Bearings are used in duplex pairs, mounted back-to-back, at the pulley end of the LGP-30 memory drum, and singly at the opposite end. These preloaded, angular-contact bearings, equipped with composition or bronze retainers, are widely used in precision-built mechanisms.

"NO ROOM FOR ERROR"

in design of desk-size LGP- 30 digital computer!

Precise performance assured in Librascope's Fafnir-equipped LGP-30

Small as a desk, but it "thinks big"! No less than 4096 words can be recorded on the magnetic memory drum of the new Royal Precision Electronic Computer LGP-30. Moreover, this compact unit, made by Librascope, Inc., a subsidiary of General Precision Equipment Corporation, can be rolled where it's needed and plugged into any conventional wall outlet.

At the heart of this versatile computer, Fafnir super-precision type ball bearings maintain the precise alignment and high sensitivity required of the drum component. Counterbored to take a wide range of thrust, and radial loadings, these bearings provide the rigidity, extremely close-running accuracy, and low torque essential in this exacting application.

Fafnir's contribution to the development of the LGP-30 is another case history example of the high caliber and comprehensive scope of Fafnir design engineering services available to *you*. Take advantage of it when you have a bearing problem. The Fafnir Bearing Company, New Britain, Conn.

FAFNIR
BALL BEARINGS
MOST COMPLETE LINE IN AMERICA

Circle 445 on Page 19

Strength—On an island off the coast of Greenland, you can find the remnants of three large meteorites which the Eskimos have named "The Tent," "The Woman" and "The Dog." Only about one half of the meteorite mass remains, because native warriors and craftsmen worked for untold centuries to rip away pieces of the heaven-sent alloy for vital weapons and tools. So it is today, that man first turns to steel when he needs a versatile metal of great strength.

If strength were the only consideration of the designer, his job would be simple: pick the strongest steel he can afford for the job. But invariably, he is enmeshed in a spider's web of other problems. He needs varying amounts of corrosion resistance, toughness, weldability, fatigue or wear resistance, formability. To cap it, he is asked to choose from a vast range of different steels, at different prices, with different combinations of properties. Then come the added complications of heat treating, and the fact that production techniques may have a profound effect on several important properties of the steel he has chosen.

But underlying all this, one fact remains: In theory, there is one best steel for any application. When you know the performance requirements and the cost problems, when you are intimately familiar with all the properties of all the available steels, you can usually settle on one that will result neither in overdesign nor underdesign. And you are almost certain to find that steel in the great family of USS Design Steels, a selection unmatched by any other producer in the world.

For careful design, when cost is a problem, the selection of the best steel should be made by a skilled metallurgist—either on your staff or ours. Write United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

United States Steel Corporation • American Steel & Wire • Columbia-Geneva Steel • National Tube
Tennessee Coal & Iron • United States Steel Supply • United States Steel Export Company

USS **United States Steel**

Please direct inquiries to advertiser, mentioning MACHINE DESIGN

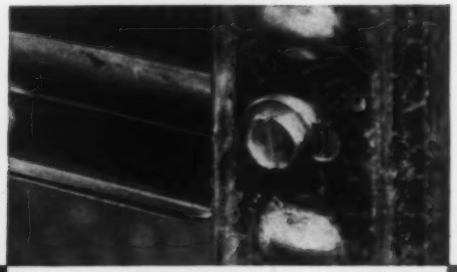
STEELS FOR DESIGN

Lower Left—Problem: Several of the stop logs fabricated by Montreal Locomotive Works for the St. Lawrence Seaway's St. Lambert Lock had to be made extra-strong to withstand greater water pressure than typical of the other locks. But to insure ease of handling and interchangeability with the other logs, they couldn't be made larger. Solution: Logs were made of USS MAN-TEN Steel, one of several USS High Strength Steels. Benefit: MAN-TEN logs are much stronger, but have same weight and size as regular stop logs.

Lower Middle—Problem: On a lift truck, every pound of weight forward of the wheels reduces load capacity. Solution: Clark Equipment Co. designed lift truck carriage assembly from USS "T-1" Constructional Alloy Steel, reducing weight of assembly by 66⅔, compared to structural carbon steel. Benefit: Pay load was greatly increased, due to USS "T-1" Steel's 100,000 psi yield strength.

Lower Right—Problem: Heil Company wanted to design a very strong, corrosion-resistant tank trailer to haul corrosive solutions. Solution: Using Type 316 USS Stainless Steel, they developed the unusual ribbed design visible in the picture. Benefit: Stainless Steel's strength helped to give greater beam strength to the tanker. Its corrosion resistance allows the tank to be cleaned easily, so it can be used to haul different liquids on different trips.

USS, Man-Ten and "T-1" are registered trademarks

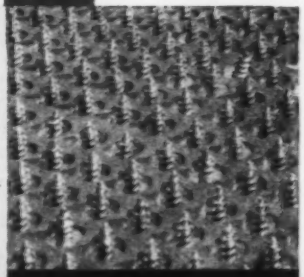


Maytag production men find ***P-K® fasteners*** *have* ***BUILT-IN SAFETY FACTOR*** *that helps save time and money!*

"Head breakage can be a major production problem, especially when it occurs in 'blind-hole' assemblies. In such cases the washer or dryer must be pulled off the line while the broken screw is drilled and removed. Salvage operations are even more costly if screw heads pop off after a unit is crated for shipment. So the toughness and breakage-resistance of fasteners can be mighty important.

"Parker-Kalon Self-tapping Screws are well engineered—hard and dependable even with high-torque, impact-type drivers. They give us the safety factor Maytag's high-quality standards demand."

Thousands of users have found P-K's "built-in" safety factor... the extra-ability to withstand highest torque without breakage... helps end annoying slowdowns, excessive rejects, assures rugged dependable fastenings in the plant—in shipment—and in the field. P-K Self-tapping Screws are available in a wide variety of types, sizes and head styles for use in steel, nonferrous metals, compositions, wood, plastic and many other applications.



PARKER-KALON® fasteners

Sold everywhere through leading Industrial Supply Distributors.

PARKER-KALON DIVISION, General American Transportation Corporation, Clifton, New Jersey. Manufacturers of Self-tapping Screws, Socket Screws, Screwnails, Masonry Nails, Wing Nuts and Thumb Screws.

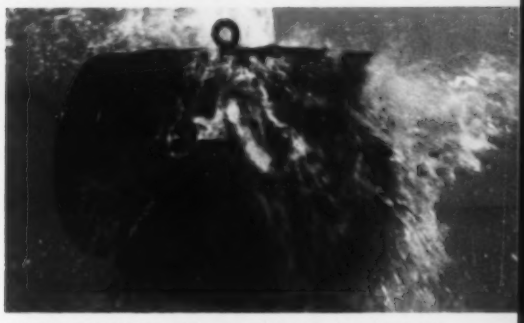
Circle 447 on Page 19

Circle 448 on Page 19→

YOU GET
DOUBLE PROTECTION
against corrosion...
against falling
or splashing liquids

Air intakes and outlets are positioned to provide complete dripproof protection.

TYPE DP
1 to 125 hp



DOUBLY PROTECTED—Wagner DP Motors offer the *double protection* of completely dripproof enclosures and rugged cast iron frames that can take rough handling and resist corrosion.

with WAGNER TYPE DP MOTORS designed to meet more application needs

Wagner Type DP Motors offer the *double protection* of rugged corrosion-resistant cast iron frames and dripproof enclosures so well designed that the DP Motor can handle many applications that formerly required splashproof motors.

These Wagner Motors are built in the new NEMA ratings that pack more power in less space, are lighter in weight and are easier to maintain.

CAN BE RELUBRICATED—Factory lubrication will last for many years in normal service—but openings are provided to permit the relubrication that adds years to motor life under severe conditions.

SLEEVE BEARING MODELS AVAILABLE

The entire line of ratings through 125 hp is available with ball bearing construction as illustrated, or with steel-backed, babbitt lined sleeve bearings that have high load carrying capacity and provide quieter operation.

Let a Wagner Sales Engineer show you how these motors can be applied to your needs. Call the nearest branch office or write for Wagner Bulletin MU-223.

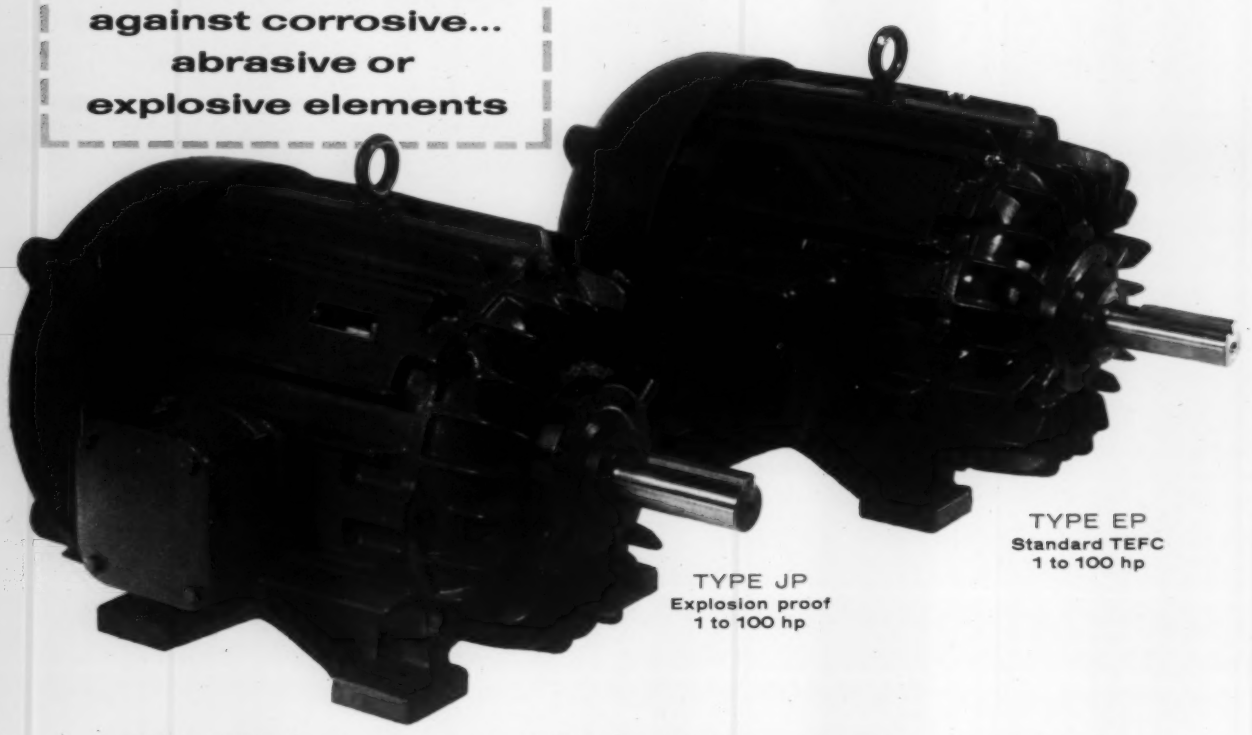
COOL RUNNING—Specially designed baffles direct cooling air through the motor to reduce stator temperature—thus increasing motor life. Blowers, cast as part of the rotor, move large volumes of air without noise or vibration.

1 to 125 HP—1750 RPM—40°C
NEMA FRAMES 182 through 445U

Wagner Electric Corporation
6400 Plymouth Ave., St. Louis 14, Missouri.

WM58-9

YOU GET
EXTRA PROTECTION
against corrosive... abrasive or explosive elements



TYPE EP
Standard TEFC
1 to 100 hp

TYPE JP
Explosion proof
1 to 100 hp

with Wagner totally enclosed motors... protected for longer motor life

If you need motors that will keep production rates up . . . that will give the continuity of service that is so important to automation . . . that will operate with complete dependability under the most severe conditions —Wagner totally-enclosed motors are your soundest choice.

Type EP Motors offer protection against corrosion, dust, abrasives, fumes, steel chips or filings. Type JP is explosion proof as well — designed and approved for use in explosive atmospheres.

NEW NEMA FRAMES—These motors are built in the new NEMA Frame sizes from 182 through 445U, with ribs that add mechanical strength and increase the surface cooling area. Effective cooling system adds to motor life.

Let your Wagner Sales Engineer show you how these protected motors can bring you savings on initial motor costs, maintenance costs and continuity of operation.

1 TO 100 HORSEPOWER—4 POLE, 60 CYCLE—NEMA FRAMES 182 THROUGH 445U

Wagner Electric Corporation

6400 Plymouth Ave., St. Louis 14, Missouri. Branches and Distributors in All Principal Cities

HEAVY DUTY BALL BEARINGS

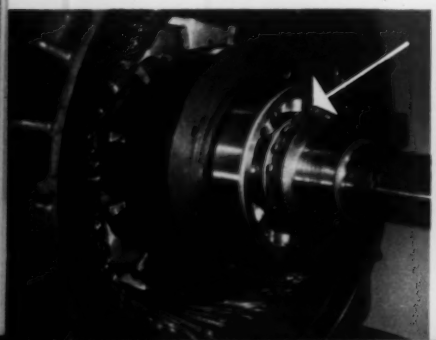
The ball bearings used in these motors are of the highest quality, with more than ample capacity to provide long troublefree service under heavy loads.

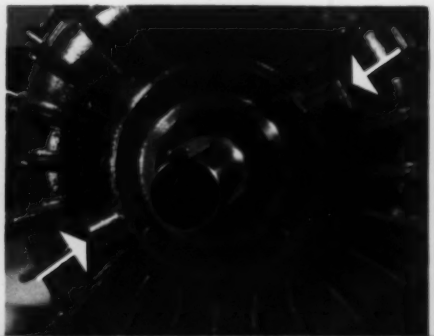
BEARINGS CAN BE RELUBRICATED

Factory lubrication will last for many years under normal service, but openings are provided to permit relubrication that adds years to motor life under severe conditions.

SEALS KEEP BEARINGS CLEAN

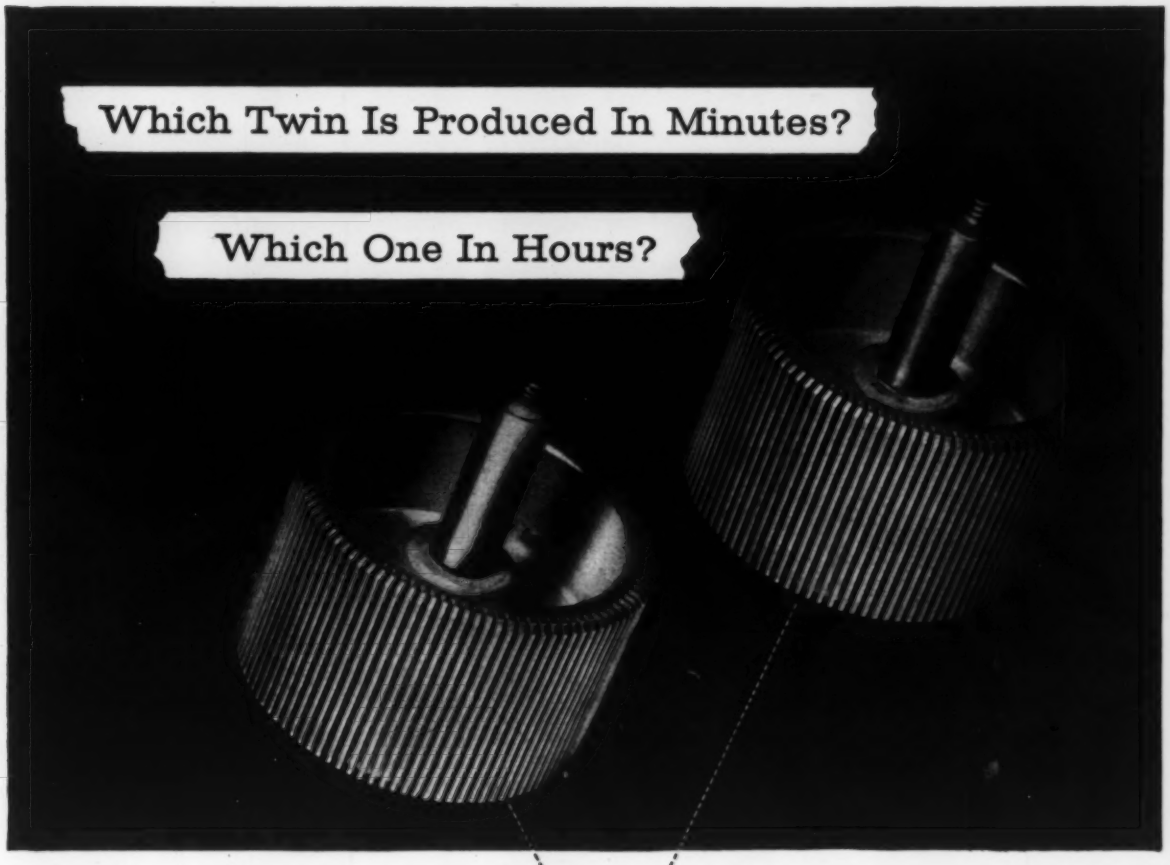
Both ends of these motors have running shaft seals to keep the bearings clean. Bearing housings are effectively sealed to prevent escape of grease.





Which Twin Is Produced In Minutes?

Which One In Hours?



These parts are identical. One, however, is produced in minutes, the other in hours. Parker-engineered die casting makes the difference.

Formerly, this part (shown left above) was machined from the solid. The threaded steel shank was inserted in a separate operation. Numbers on the face (not shown) had to be stamped . . . still another operation. *Total production time per piece was measured in hours.*

Now, this same part, including the steel insert and the face numbers, is produced as a unit by Parker-engineered die casting. Trimming of gate and fins is the only secondary operation. *Total production time per piece is now measured in minutes.*

Here is just another example of the way Parker-engineered die castings save you money.

This skill and experience can solve problems—and save money—on *your* components parts. Just call the nearest Parker sales engineer or write the factory direct.

Parker White Metal Company • 2153 McKinley Ave., Erie, Pennsylvania

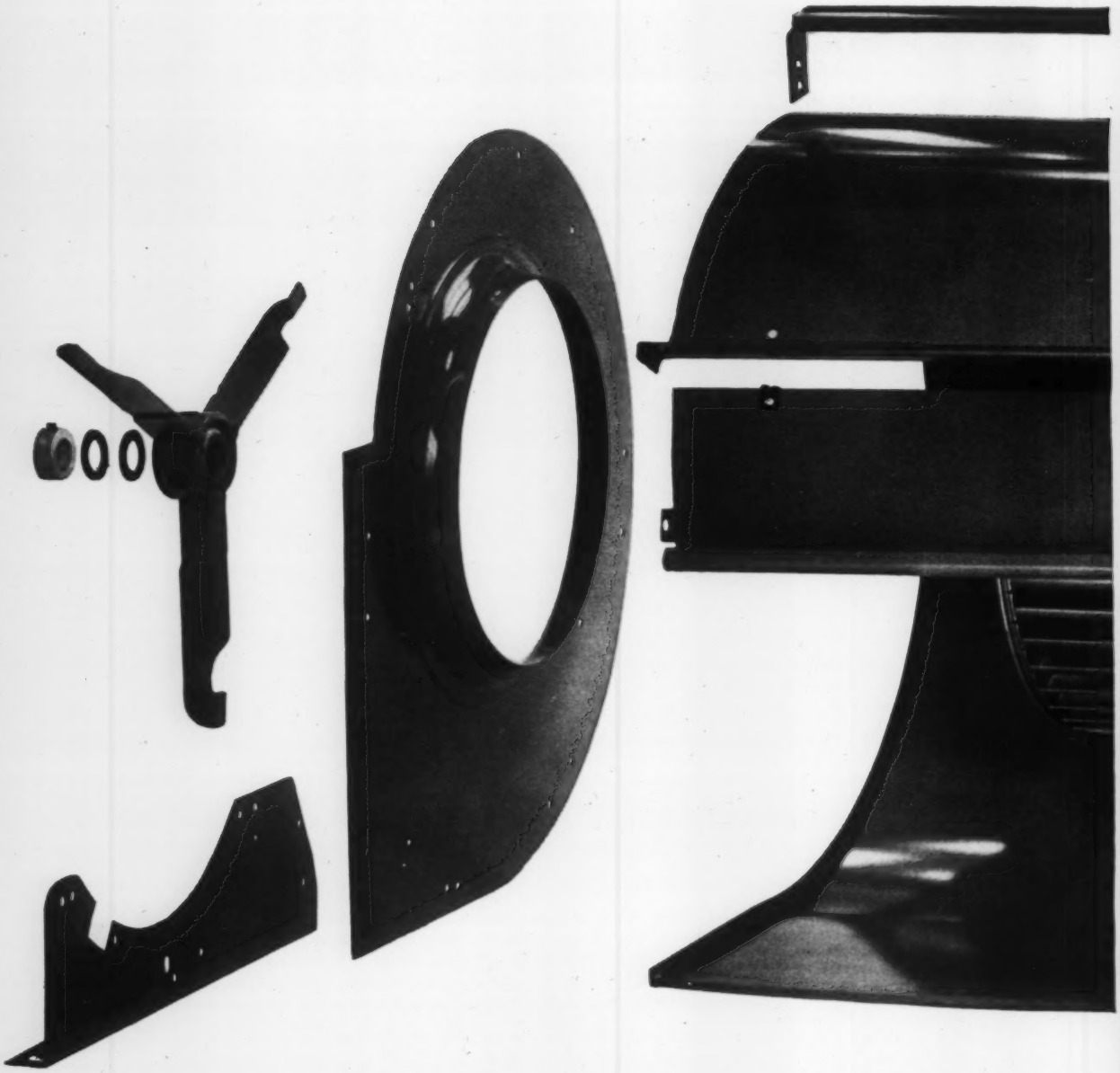
PARKER SALES ENGINEERS

BELLEFONTE, Penna.
Warren G. Olson • 420 East Linn Street
CHICAGO 49, Ill.
Ollie J. Berger Company • 2059 East 72 Street
CINCINNATI 14, Ohio
William H. Broxterman • 2430 Central Parkway
DETROIT 35, Mich.
Hodgson-Geisler Co. • 18917 James Couzens
GIRARD, Penna.
Daniel F. Marsh • 35 Chestnut Street
LONG BEACH 11, California
R. W. Fletcher • 2803 Loomis Avenue
MINNEAPOLIS 16, Minnesota
O. R. Kreutziger • 6524 Walker Street
PHOENIX, Arizona
Fred B. Larsen • 6108 North 11 Avenue
ST. LOUIS 8, Mo.
Frank May • 4378 Lindell Boulevard
SYRACUSE, N. Y.
J. C. Palmer • 712 State Tower Bldg.
WILTON, Conn.
Girard L. Palmer • Belden Hill Road
WINTER PARK, Florida
Duane P. Davis • 110 South Orlando Avenue
Box 26

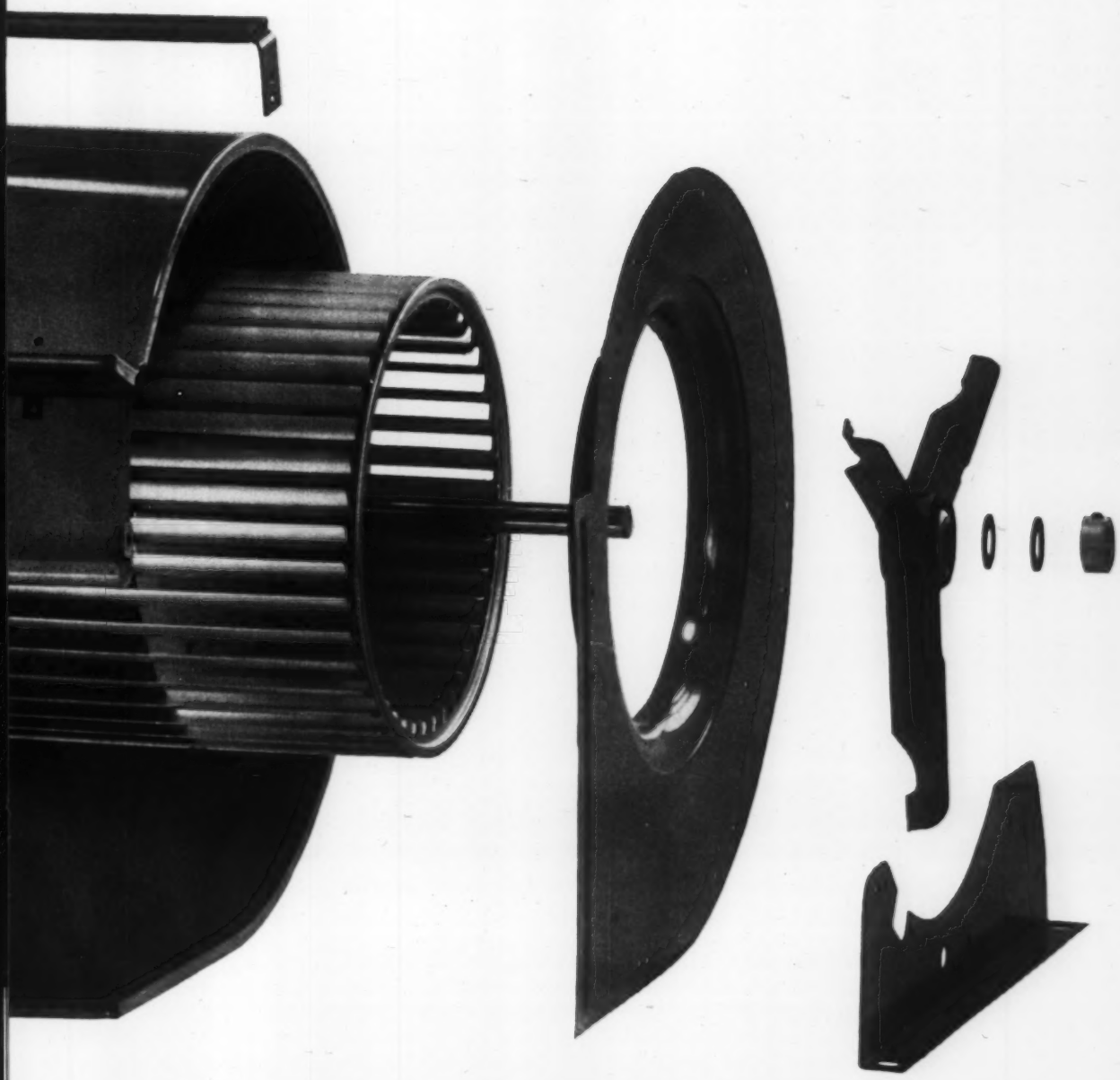
PARKER

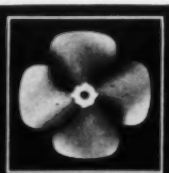
high pressure ALUMINUM and ZINC die castings
POWDERED METAL PARTS

Circle 449 on Page 19



EXPLOSION!

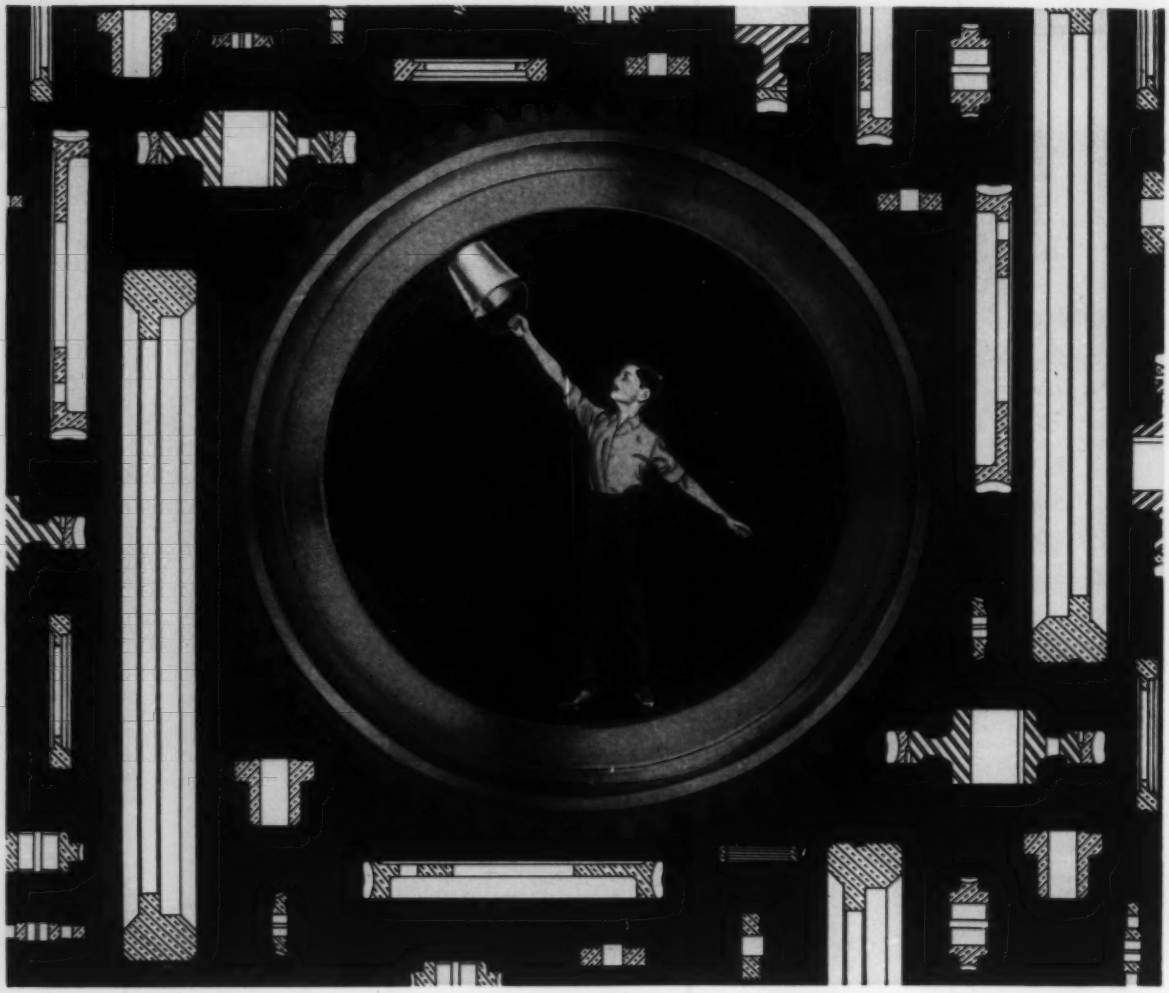




The new Torrington line of Vari-Basic blower units has quietly exploded all previous concepts of quality, flexibility, versatility and structural cleanliness. ▪ And the exploded view shown here tells the inside story of why: ▪ The famous Center Lock Airotor wheel design ... permanently lubricated bearings ... spot-welded heavy steel construction ... superb finish ... four-way variability to meet directional flow requirements ... interchangeability with existing standard equipment. ▪ And Torrington's flexible marketing policy makes these components available singly or in combination. For full information, *talk to Torrington!*

THE TORRINGTON MANUFACTURING COMPANY

TORRINGTON, CONNECTICUT • VAN NUYS, CALIFORNIA • OAKVILLE, ONTARIO



Centrifugally cast gear blanks...in BRONZE ...are stronger, last longer!

Big gears and intricate shapes — our specialty!

We cast many blanks centrifugally . . . in sizes up to and even beyond 72″ in diameter. Because centrifugally cast gears have proved their added strength, toughness and long-wearing characteristics for many problem applications.

Laboratory testing and field experience show that physical and mechanical properties of centrifugal castings are as much as 10-15% better than those of most static castings.

But whatever the shape or size of the gear blank NBD can cast it for you (centrifugally or statically) in gear bronze, aluminum bronze, manganese bronze —to your specifications. Want iron or steel hubs cast in? We can do it. Want castings furnished rough, rough machined, or finished machined? Want sand castings, shell moldings, chilled rim or chilled three sides? You name it.

Take advantage of NBD's experience. Three strategically located plants are available to give you fast service. Call or write for quotes or information.

AMERICAN Brake Shoe COMPANY

NATIONAL BEARING DIVISION

717 Grant Building, Pittsburgh 19, Pennsylvania

PLANTS IN: CHICAGO, ST. LOUIS, MEADVILLE, PA.

Circle 451 on Page 19

Fastener Facts

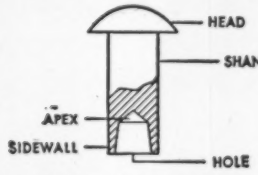
DESIGN PRODUCTION & PURCHASING DATA

by Paul Tunison, Chief Engineer — Judson L. Thomson Mfg. Co.

FASTENING WITH SEMI-TUBULAR RIVETS

WHY RIVETS?

You specify rivets when you want strong, permanent fastening at low cost. However, secure fastening is not their only function. You can also use them as fulcrums, pivots, cam followers, electrical contacts, studs, stops and in many other applications.



Typical semi-tubular rivet

WHY SEMI-TUBULAR RIVETS?

You specify semi-tubular rivets when you want to combine the high shear and compression strength of solid rivets with low-cost, high-speed fastening. The required strength is inherent in the design of Thomson Semi-Tubular Rivets.

Shallow holes in solid shanks distinguish semi-tubular rivets from other types. The hole is seldom deeper than shank diameter. Its depth is determined by clinch requirements of specific applications. A general rule is to select a rivet with length equal to the thickness of the materials *plus* 55% of the diameter of the shank. A Thomson engineer can quickly specify the correct rivet length and hole depth for any particular semi-tubular riveting application.

Semi-tubular rivet applications call for pre-drilled or punched holes in the materials to be fastened: metals, plastics, wood, ceramics and other hard materials. The size of the prepared holes is an important design consideration. When holes are too small, rivets choke. When too large, rivets buckle. To avoid either error, make sure that each hole is about 7% larger than the maximum shank diameter of the rivet. In most cases, the setting process causes shank expansion sufficient to fill the hole. Again, Thomson engineering is at your service to help you match rivet and hole sizes.

High shear strength of semi-tubular rivets is further assured by Thomson production methods. All Thomson Semi-Tubular Rivets are made from specially prepared wire by the cold heading or upsetting process. This results in fasteners with the uniform structure and *inherent strength of forgings* . . . properties not achieved by screw-machine rivet production.

Standard materials used to produce Thomson Semi-Tubular Rivets include aluminum, brass, copper, nickel-silver, low-carbon steel and stainless steel. For special electrical and electronic contacts, coin silver, fine silver, palladium and other precious metals may be specified.

Finishing to specifications is another service of interest to design engineers. Rivets can be plated with brass, cadmium, copper, nickel, tin, zinc, etc. Morever, they can be oxidized or finished in japanned colors to match the original equipment or product.

Low fastening costs result from the application of Thomson Semi-Tubular Rivets with automatic rivet-setting machines. The low cost of rivets, as compared with most other fasteners, combined with high machine speeds invariably leads to production line economies. Machines are low in initial cost and require little maintenance. Furthermore, they can be operated by unskilled labor.

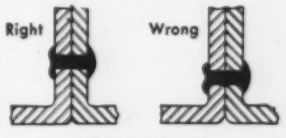
FLOOR-TYPE FOOT-OPERATED — FLOOR-TYPE MOTOR-OPERATED

HIGH PRODUCTION RIVET-SETTING MACHINES

Thomson has developed more than 200 styles of modern, high speed machines which can be adapted to innumerable fastening jobs. These machines are divided into three basic models: floor type with foot-pedal operation, floor type with motor operation, and bench type with motor operation. All permit automatic hopper feed for maximum speed, and some motor driven floor models are equipped for multiple rivet-setting.

Special work-handling devices accelerate riveting operations. Radial or turret feeds are common accessories for machines geared to high-production fastening of parts, as are all types of special loading fixtures. Thomson selects the proper machine to do your job most efficiently and custom-tools it to fit your fastening requirements.

DESIGN PRACTICES

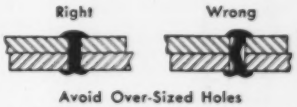


Clearing Corners

Allow plenty of room between hole and flange for anvil clearance.

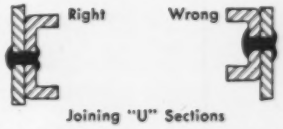
Joining Thick and Thin Sections

Insert rivet from thin-gage side and clinch against heavier section.



Avoid Over-Sized Holes

When holes are too large, rivet may buckle during clinching operation.



Joining "U" Sections

The wider the channel, the easier the riveting operation. Clinching inside "U" leaves driving and feeding mechanisms out in the open.

DESIGN & ENGINEERING SERVICE

We will gladly evaluate your fastening problems at little or no cost. Contact us while designs can still be modified for lowest cost fastening method. Simply send sketches, prints, or preferably samples of actual work.

FREE "FASTENER FACT FILE"

Be one of the first to profit from our new manual on all phases of riveting. It covers rivet types, applications, materials, finishes, and other factors that determine selection of the right design, rivet and machine for cutting fastening costs. Request your copy today. Write Judson L. Thomson Mfg. Co., Dept. B, Waltham 54, Massachusetts.

JUDSON L. THOMSON MFG. CO., WALTHAM 54, MASS.

Circle 452 on Page 19

The Clamp Screw locks hub to shaft for permanent alignment. Hub is locked in one piece so there is no distortion as set screw is drawn down.
The Set Screw locks key in place, prevents "key drift," a necessary safety feature.

In Worthington QD Sheaves these extra

2 SCREWS MAKE

Exclusive features of Worthington QD Sheaves...

EASY ON! Two-piece design lets you install the sheave *one part at a time*. No heavy rim and hub combination to inch into place; the tapered hub slides easily on the shaft, is locked by the clamp screw for permanent alignment. The set screw locks key. Then the sheave rim slides easily into position on the taper-seat of hub because the large end of taper in sheave starts engagement with small end of taper on hub. Heavy hex-head bolts complete the assembly.

EASY OFF! Remove the big pull-up bolts and use two as jack bolts for easy rim removal. To change speed it's simple to mount a larger or smaller sheave on the hub which, because of clamp screw, remains aligned on shaft. You can install or remove one part at a time.

THE DIFFERENCE

ALWAYS TIGHT! Severe shock or reversing loads cannot loosen the sheave. Tightening the pull-up bolts locks the split-tapered hub to the shaft as tight as if the sheaves were integrally cast with shaft. The set screw anchors the key in position.

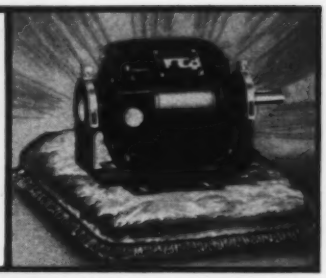
COMPLETE STOCK! You can get Worthington QD sheave stock service anywhere in the U. S. More than 350 distributors carry Worthington sheaves and Worthington-Goodyear Green Seal V-belts. For 100 page Multi-V-Drive Manual on how to select the right sheave and V-belt write to Section 79-9, Worthington Corporation, Harrison, New Jersey.

WORTHINGTON

Circle 453 on Page 19

tailor-made for You

. . . and every one a perfect fit

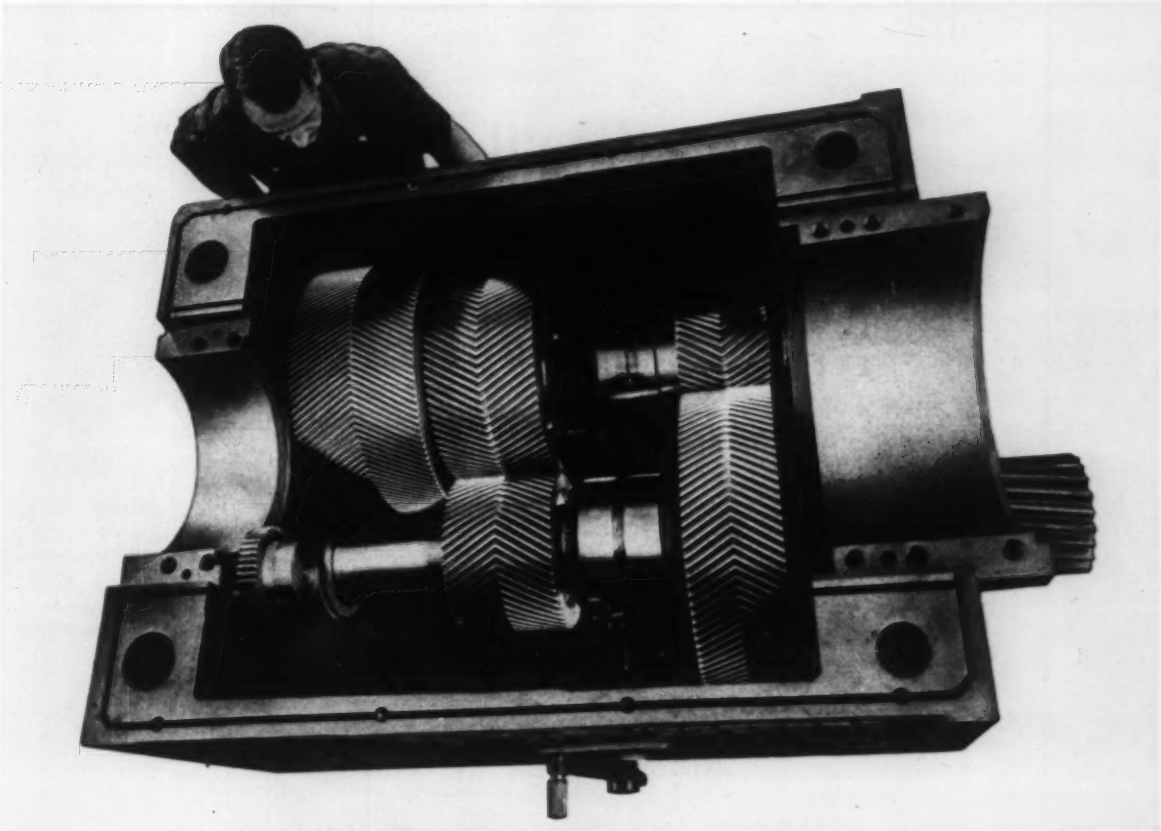


No Sir, no ready-made here. Emerson-Electric motors are custom-engineered for your product . . . *designed* for you, *produced* for you and *priced* for you. It is no longer necessary to design your product around a *standard* motor. Emerson-Electric engineers will work with you through every stage of development. You get the product you want with a motor that EXACTLY suits your purposes . . . a custom-engineered motor. Call, wire or write Dept. M-308 today, The Emerson Electric Mfg. Co., St. Louis 21, Mo.

EMERSON-ELECTRIC
of St. Louis

Since 1890

Circle 454 on Page 19



You can tell at a glance

THESE ARE PRECISION GEARS

Aside from the obviously fine finish of the gears in the large lathe headstock above, there's another sure clue to their precision—the teeth are continuous across the face. That is a characteristic of herringbone gears made on a Farrel-Sykes generator, although the gears can be made with a center groove when required.

The accuracy inherent in the operating principle of the Farrel-Sykes gear generating machine assures accurate tooth spacing, profile and helix angle. Thus, you can be sure that Farrel® herringbone gears will operate smoothly, quietly and efficiently over a long service life.

When you specify Farrel gears in your designs, you get the kind of accuracy needed for today's machines and machine tools. We shall be glad to discuss your requirements and supply further information.

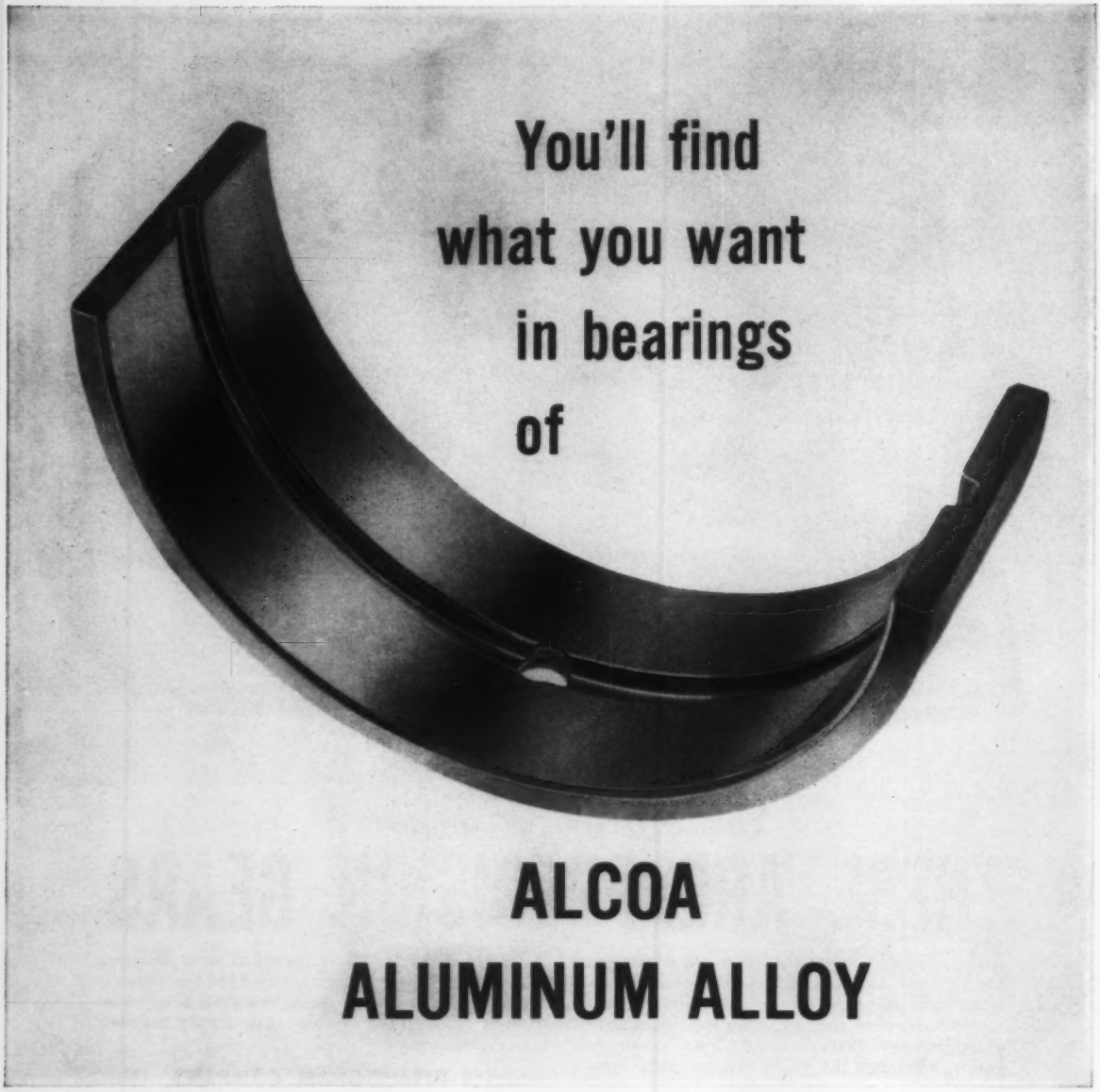
FARREL-BIRMINGHAM COMPANY, INC.
ANSONIA, CONNECTICUT

Plants: Ansonia and Derby, Conn., Buffalo and Rochester, N. Y.
Sales Offices: Ansonia, Buffalo, Boston, Akron, Ann Arbor (Mich.), Chicago, Minneapolis, Los Angeles, Salt Lake City, Tulsa, Houston, Fayetteville (N. C.)
European Office: Piazza della Republica 32, Milano, Italy

FB-1139

Farrel-Birmingham®

Farrel® gears are made in all types that operate on parallel axes.



Ability to carry heavy loads . . . up to 10,000 psi on projected area.

Cooler Running . . . Aluminum is the best heat conductor among bearing materials, thus runs cooler . . . as much as 20° by actual test.

Good Conformability . . . Aluminum has good ductility, conforms readily to misalignment of shafts or nonparallel pins.

Ideal Embeddability . . . Aluminum embeds particles better than bronze, not as deeply as babbitt; dirt particles roll out easily and are trapped by filter.

Corrosion Resistance . . . Aluminum resists corrosion, is unaffected by additives in oils, needs no protective coating.

Design Flexibility . . . Aluminum has it; structural properties allow for greater flexibility in design . . . ease of machinability, too!

For more information on the unmatched combination of advantages in solid aluminum alloy bearings, call your nearest Alcoa sales office. Or, write to Aluminum Company of America, 1986-E Alcoa Building, Pittsburgh 19, Pennsylvania.

ALCOA ALUMINUM BEARINGS

Your Guide to the Best in Aluminum Value

"ALCOA THEATRE"
Exciting Adventure
Alternate Monday Evenings

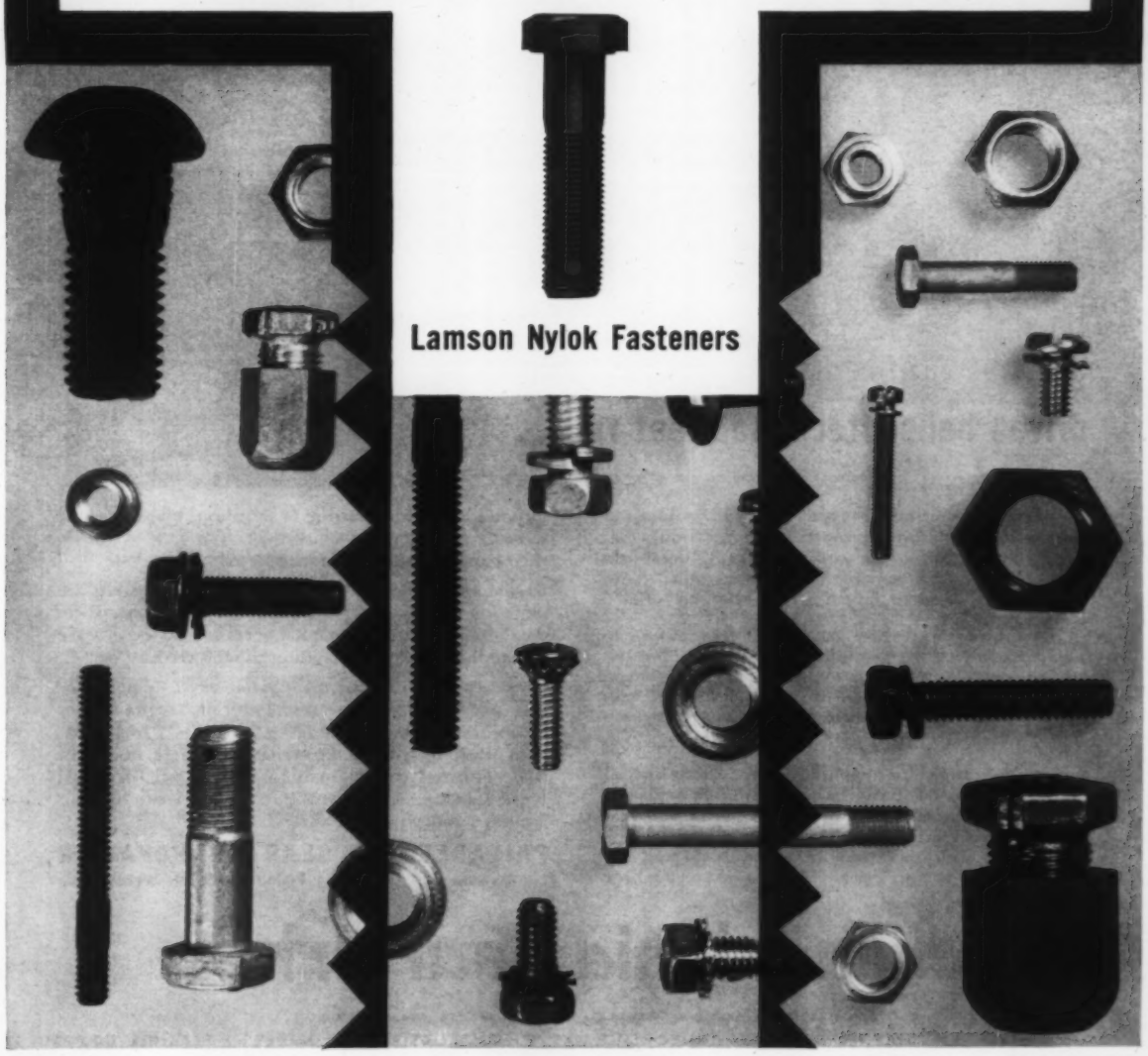
Circle 456 on Page 19

Other Companies' "Specials" are often "Standards" with us!

Normally the difference between a "Special" fastener and a "Standard" is a question of sales volume. Consequently, when a fastener we used to consider a "Special" begins to sell in large quantities, it becomes a Lamson "Standard". This is a great advantage for the buyer because volume manufacturing and selling often lowers prices and many times the fastener can be delivered fast — direct from stock. We invite you to check with us if you have a "Special" fastener problem. Maybe we have a "Standard" solution to it.

The Lamson & Sessions Co.

5000 Tiedeman Road, Cleveland 9, Ohio • Plants at Cleveland and Kent, Ohio • Chicago • Birmingham

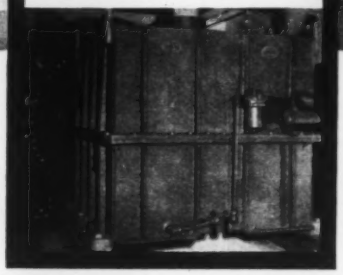


Lamson Nylok Fasteners

Circle 457 on Page 19

(Above) Cutting 64 inch spiral bevel gear on new precision gear generator.

(Below) Interior of rotor test stand showing Philadelphia Spiral Bevel Reducer. 1300 hp motor is in background.



Special 1300 hp Philadelphia Reducer drives helicopter rotor test rig...

Testing 90-foot helicopter rotors involved problems of torque and vibration, plus precise speed control and test rig maintenance. Kaman Aircraft Corp., Bloomfield, Conn., found the answer in a special spiral bevel Philadelphia Reducer driven by a 1300 hp variable speed DC motor.

This Philadelphia designed drive completely eliminated vibration and torque variation previously encountered in engine driven rigs. Maintenance is simpler. Precise speed control can be obtained at rotor speeds from 200 to 400 rpm.

For any right angle drive application, standard or special, Philadelphia Spiral Bevel-Helical Reducers will take more abuse and last longer under the most severe load conditions. One of the reasons is that all Philadelphia spiral bevel gears and pinions are heat treated and hardened *after* they are cut . . . then lapped to a mirror-like finish. Helical Gearing is precision hobbed on the newest, most modern equipment. The gear teeth are then crown shaved and induction hardened.

Result: better tooth contact, longer gear life. Units are vibration-free and quieter. On special applications, where conditions warrant, both spiral bevel and helical gearing can be furnished with precision ground teeth.

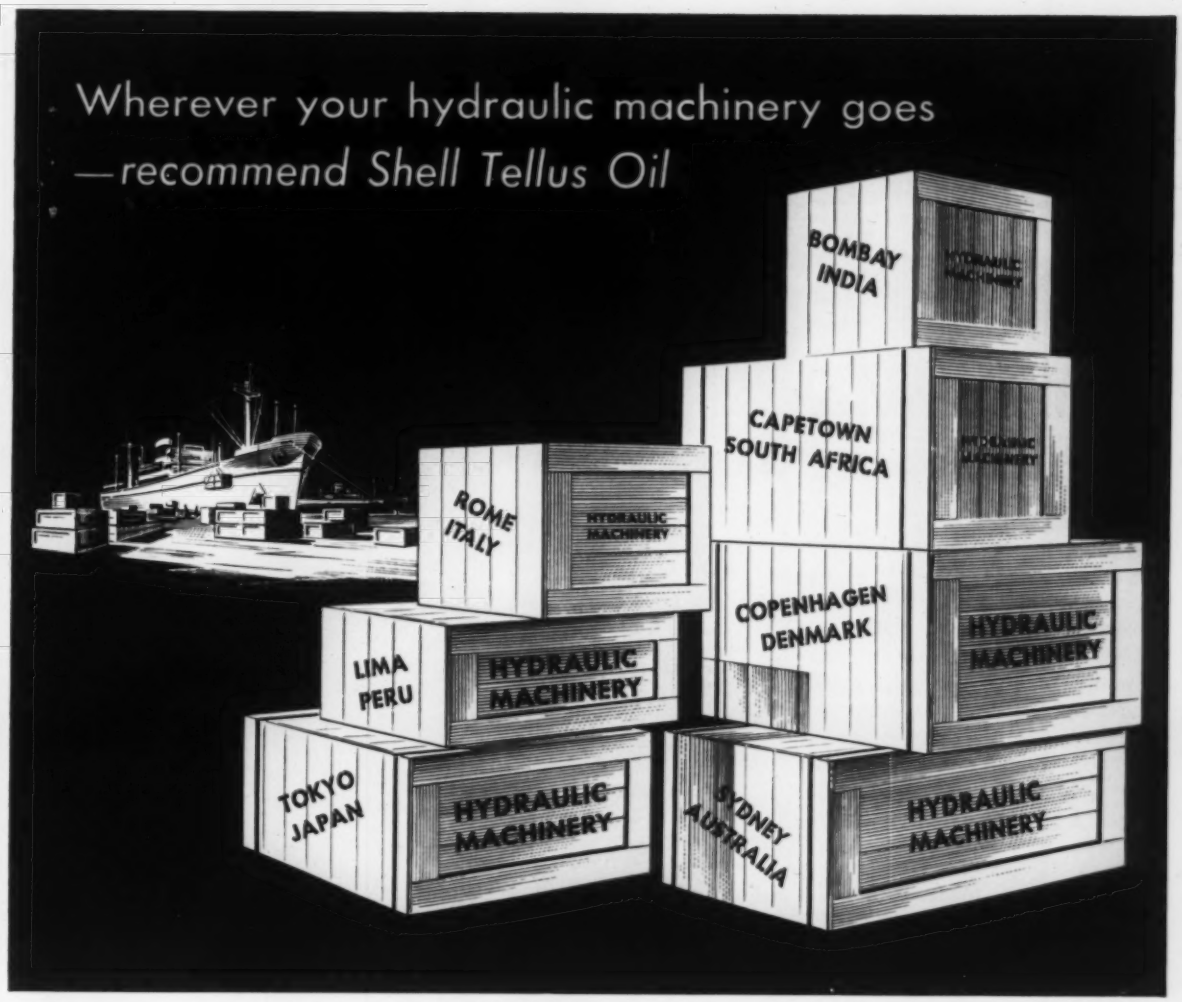
You can select a Philadelphia Spiral Bevel Reducer—or have one specially built—to suit your precise needs. Our Spiral-Bevel units provide ratios as low as 1 to 1, or as high as 238 to 1. Units are available in single, double or triple gear reductions—in both vertical and horizontal types. Catalog SB-57 describes them all. Write for your free copy today.

PHILADELPHIA GEAR CORPORATION
Erie Avenue and G Street • Philadelphia 34, Pennsylvania

philadelphia gear drives

Offices in all Principal Cities • Virginia Gear & Machine Corp., Lynchburg, Va.

INDUSTRIAL GEARS & SPEED REDUCERS • LIMITORQUE VALVE CONTROLS • FLUID MIXERS • FLEXIBLE COUPLINGS



Its performance and name are the same around the world

Other Outstanding Shell Industrial Lubricants

Shell Rimula Oils—for heavy-duty diesel engines

Shell Talona R Oil 40—anti-wear crankcase oil for diesel locomotives

Shell Alvania Grease—multi-purpose industrial grease

Shell Turbo Oils—for utility, industrial and marine turbines

Shell Dromus Oils—soluble cutting oils for high-production metal working

Shell Macoma Oils—for extreme pressure industrial gear lubrication

Shell Voluta Oils—for high-speed quenching with maximum stability

Shell Tellus Oil is top-rated as both a lubricant and a control fluid for complex hydraulic systems. Its ability to combat oxidation, rust, sludge-formation, wear and foaming has earned it nationwide popularity.

You may be glad to know that the hydraulic-operated equipment you manufacture can now obtain the same efficient protection in other countries of the world. Tellus* Oil is available to your customers abroad. With it they can enjoy the same performance that your domestic customers rely upon.

For more complete information on Tellus Oil, write Shell Oil Company, 50 West 50th Street, New York 20, New York, or 100 Bush Street, San Francisco 6, California.

*Registered Trademark

SHELL TELLUS OIL

SHELL

Circle 459 on Page 19

CUT COSTS, IMPROVE DESIGN AND PERFORMANCE WITH R/M PRODUCTS

RUBBER

Write today for free booklet shown: full details on a wide variety of industrial rubber products.
Manhattan Rubber Division, Raybestos-Manhattan, Inc.
Passaic, N.J.

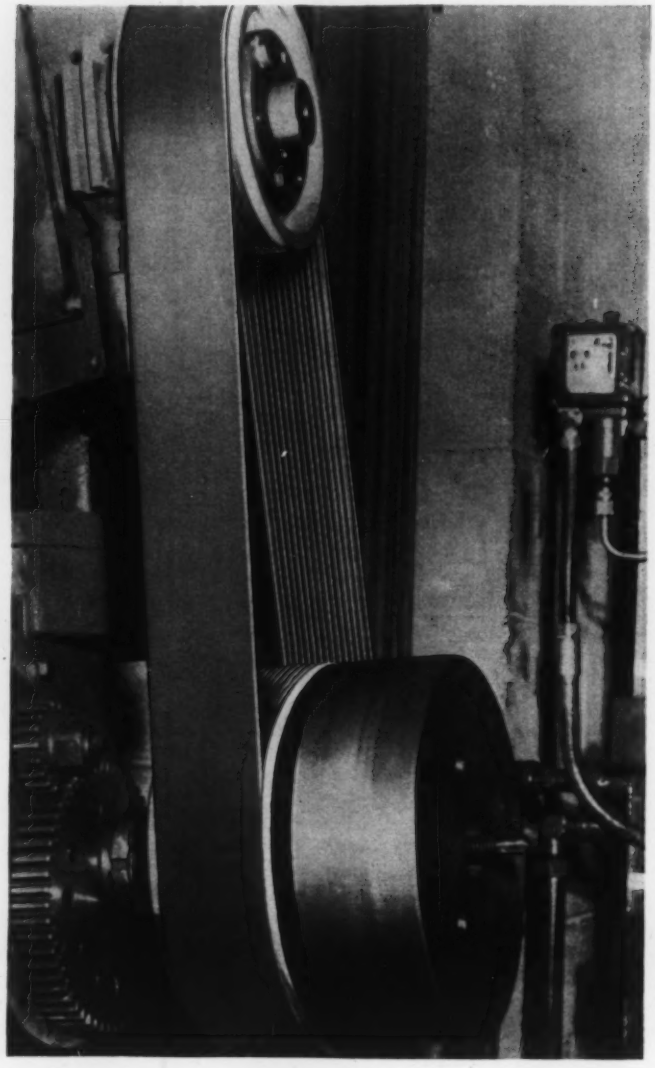
R/M *Poly-V*® Drive

MORE POWER—LESS SPACE

Space saving advantages of R/M's patented Poly-V Drive has proved the answer to difficult drive problems for a wide range of applications. Use of Poly-V on this planetary milling machine, for example, almost *doubled* power capacity of the machine's drive . . . *without* increasing space requirements!

R/M Poly-V Drive employs a single, endless parallel V-ribbed belt running on sheaves designed to mate precisely with the belt ribs. Higher horsepower capacity per square inch of the single unit belt permits use of *narrower* sheaves. You get up to 50% *more* power in the *same* space as a standard multiple V-belt drive . . . or *equal* power in as little as ⅓ the space—with less shaft overhang, less drive weight.

Poly-V's single unit belt completely eliminates V-belt matching problems, helps assure constant pitch diameter and speed ratios from *no* load to *full* load. Stronger, cooler running, longer lasting Poly-V Belt is heat resistant, oilproof and non-spark. Just *two* cross sections of Poly-V Belt meet every heavy duty power transmission requirement. If you have a power transmission problem, let the R/M engineers who developed Poly-V* Drive assist you in determining the drive that will best meet your requirements. Write for Poly-V Bulletin 6638.



*Poly-V is a registered Raybestos-Manhattan trademark.

Wherever your problems require Poly-V* Drives, V-belts, flat transmission belting, conveyor belts, rubber hose, precision molded or extruded parts . . . rely on R/M specialists to work with you.

R/M

Brake Blocks, Linings and Clutch Facings

Mechanical Packings and Gaskets

Abrasive and Diamond Wheels

Industrial Drive Belts

Industrial and Automotive Hose

Conveyor Belts

Circle 460 on Page 19A

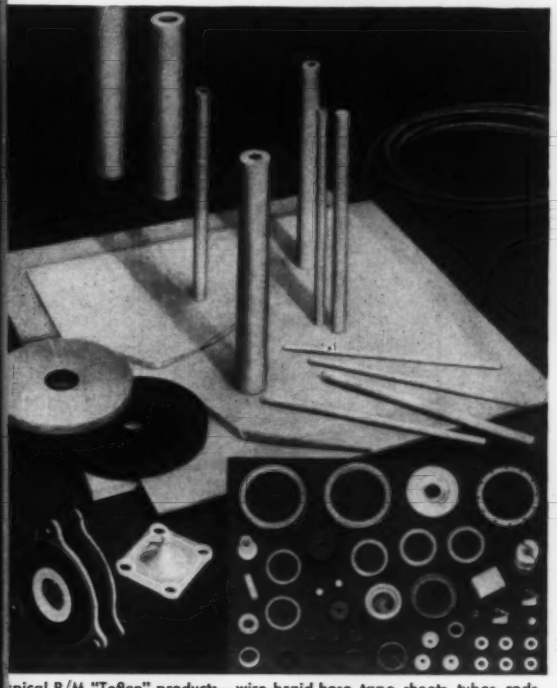
SPECIALISTS IN ASBESTOS, RUBBER, SINTERED METAL, ENGINEERED PLASTICS

PLASTICS

Write for free booklet, which provides valuable information on a variety of R/M plastic products.
Plastic Products Division, Raybestos-Manhattan, Inc.
Manheim, Pa.

PACKINGS

Complete information on packings shown and many others is given in free booklet. Send for it today.
Packing Division, Raybestos-Manhattan, Inc.
Passaic, N.J.



ypical R/M "Teflon" products—wire-braid hose, tape, sheets, tubes, rods, askets, expansion joints, etc.

R/M Piston Cups and Vee-Flex Packing Rings are among the many precision engineered R/M Packings

Dependable quality in R/M TEFLON* parts and components

Our long experience and unparalleled facilities suggest Raybestos-Manhattan as your headquarters for any "Teflon" products you may need. R/M laboratories and engineers have had outstanding success in the developing and testing of "Teflon" products. This is matched by R/M's fabricating facilities and resourcefulness. We are constantly turning out those "can't be done" jobs.

We invite you to bring us your "Teflon" problems, especially those which involve close tolerances and intricate design. Whether your need is for steel wire-braid hose, custom-machined or molded parts or components, or applications using bondable "Teflon" sheet or tape, your specifications will be followed with painstaking accuracy. You may be able to use to advantage similar products made of Raylon, the R/M trade name for mechanical grade "Teflon" which has many of the properties of virgin "Teflon."

*A Du Pont trademark

Get better performance from R/M Molded Packings

Accurate molding methods and precise quality controls assure you of outstanding performance when you specify molded hydraulic and pneumatic packings manufactured by Raybestos-Manhattan. Coupled with this is the extra benefit you get from the engineering skills and experience accumulated by R/M over many years as a leading manufacturer of mechanical packings. This advantage is demonstrated in such R/M products as piston cups and Vee-Flex* Rings.

R/M Piston Cups, available in Neoprene or Buna-N and duck or in Buna-N and asbestos. Compounds have been carefully developed by R/M's chemists to give maximum service for a wide range of applications. Low friction, high resistance to extrusion.

Vee-Flex Rings, made in five types, are self-sealing, self-adjusting. Designed to form a tight seal against stuffing box wall and shaft during pressure stroke and to reduce pressure on return stroke. Effective seal at all pressures.

RAYBESTOS-MANHATTAN, INC.

FACTORIES: Passaic, N.J. • Bridgeport, Conn. • Manheim, Pa. • Paramount, Calif. • No. Charleston, S.C.
Crawfordsville, Ind. • Neenah, Wis. • Peterborough, Ontario, Canada

Rubber Lined and Covered Equipment

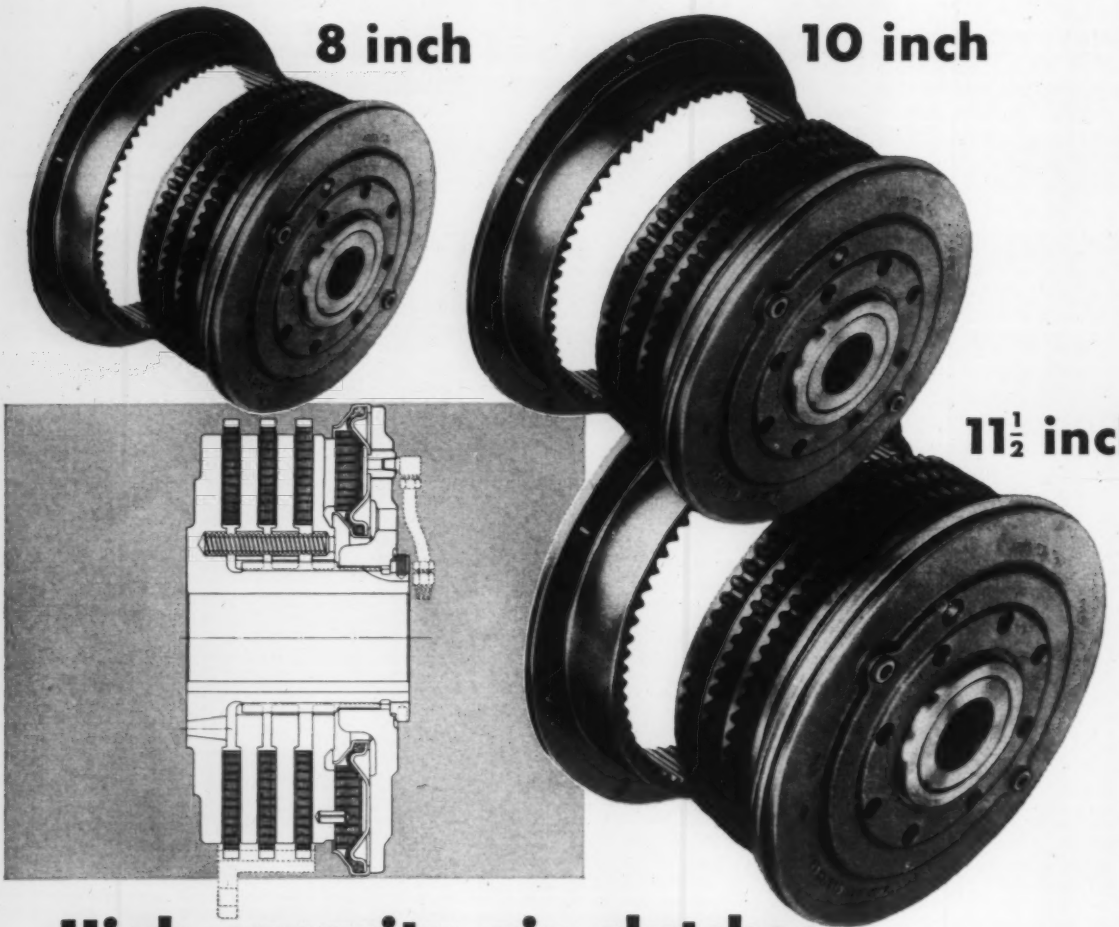
Sintered Metal Friction Elements

Asbestos Textiles

Industrial Adhesives

Teflon Tape, Packings, Sheets, Rods, Tubes

Engineered Molded Rubber and Plastics



High capacity air clutches ... up to 40% less in cost

Having clutch problems? ... Then try the new low-cost Twin Disc 8, 10 and 11½-inch PO Air Clutches. You'll find in these new clutches all the quality and dependability associated with the entire PO Air Clutch line—*plus these important benefits:*

- **New design permits highest capacity at up to 40% less cost than comparable remote-controlled units.**
- **Torque capacities to 3480 lb.-ft.**
- **Available in triple-plate, double-plate and single-plate construction.**
- **Exclusive cartridge-type reinforced neoprene diaphragm eliminates leakage ... provides longest life.**
- **Constant torque capacity without adjustment ... self-compensating for wear.**
- **Narrow width permits replacement of old-style drum or band clutches ... without extensive modification or redesigning.**
- **Suitable for air systems up to 130 pounds per square inch.**

These new PO Air Clutches are adaptable wherever the convenience of remote air control is desired. They already have proved themselves in such heavy-duty applications as rock crushers, tractor winches, pipe-extruding machines, drilling rigs, machine tools, pug mills and other industrial equipment.

Addition of the new clutches extends the Twin Disc PO Air Clutch line from 8 to 36 inches in diameter ... to 127,100 lb.-ft. in torque capacity. There's a PO Clutch for virtually every application requiring convenient remote control for connecting and disconnecting power. Write Twin Disc Clutch Company, Racine, Wis., for complete details.

TWIN DISC

TWIN DISC

Friction Clutches and Fluid Drives

TWIN DISC CLUTCH COMPANY, Racine, Wisconsin • HYDRAULIC DIVISION, Rockford, Illinois

MACHINE DESIGN
May 29, 1958

A Key to Recovery

FROM where we sit we discern a trend which has received no publicity and perhaps is not generally realized: In recent months design engineering activity seems to have skyrocketed. Demand for copies of MACHINE DESIGN has swamped our facilities, and our backlog of unfilled requests already has passed the thousand mark.

This concerted effort on new and improved design is hastening the day when current models of consumer and capital goods become obsolete. Our generally high standard of living has been influenced largely by our eagerness to discard the old and embrace the new. But a major factor in the present slowdown seems to be the willingness of both the public and industry to postpone purchases of new products and equipment.

Whatever the reasons behind consumer reluctance, there is a potent reason why industry tends to hold back. That is our unrealistic depreciation policy on capital equipment.

Steady improvements in the machinery of production hitherto have made possible annual productivity increases which have almost kept pace with the rising cost of labor. But as soon as a new machine has been bought, its owner must set up a sort of savings account toward the purchase of a replacement. The more he can save each year the sooner he can upgrade his facilities with new machinery.

However, present tax allowances offer no incentive to fast writeoff. As a result, manufacturers are "making do" with obsolete equipment pending the day when they have written off the original investment. Meantime they find it increasingly difficult to operate the older machinery profitably in the face of rising wage costs. And the machinery manufacturers languish for lack of orders.

As we started out to say, machinery manufacturers and their design engineers already are doing their part to pull us out of the recession. Government can help, not so much by grandiose vote-getting schemes as by less dramatic but equally effective means such as more liberal depreciation allowances on capital equipment.

Much of industry is expected to amortize in 15 to 25 years equipment that makes products with useful lives of five years or less—an evident absurdity. Long-range, the entire depreciation policy needs overhauling to suit the space age. Meantime, emergency proposals for fast writeoff under certain conditions are now before Congress. Enactment of such provisions could spark a major upturn in industrial activity.

Your Congressman should know how you feel about this. Why not write to him today?

Colin Carmichael

EDITOR

How to cut drafting time, errors, and costs:

Shop Practice Standards

take the guesswork

By **JOSEPH A. CHINGAS**
Design Engineering Manager
W. L. Maxson Corp.
New York, N. Y.

COMMUNICATION within the ranks of scientists and engineers has developed to a high state of perfection and precision. Ideas, specifications, and solutions are conveyed in terms that can be applied with as much precision as is needed. Of course, these specifications are of little practical use unles they can be interpreted into physical reality. To do this, an abstraction specified in an engineer's medium must be translated into an altogether different language, a language meaningful to shop, purchasing, and quality-control personnel.

This is the language of the blueprint. How adequate is it? Is it specific and without ambiguity? To explore this language, examine a drawing of a simple part, such as in Fig. 1. Conventional symbols and notes are used; almost any machine shop would accept this drawing as a basis for quoting a price. However, are the specifications complete? Unfortunately, no. Altogether, 48 significant specifications are missing:

Ten plane surfaces are delinated:

1. How flat must each surface be?
2. How square must each be?
3. How parallel to each other must they be?
4. The two upper surfaces are shown aligned. What is the alignment tolerance? Can each individually be 1.000 ±0.002 of the lower surface?
5. The lower surface is a datum. Is it flat? Within what tolerance? If it is not precisely flat, what is the datum?

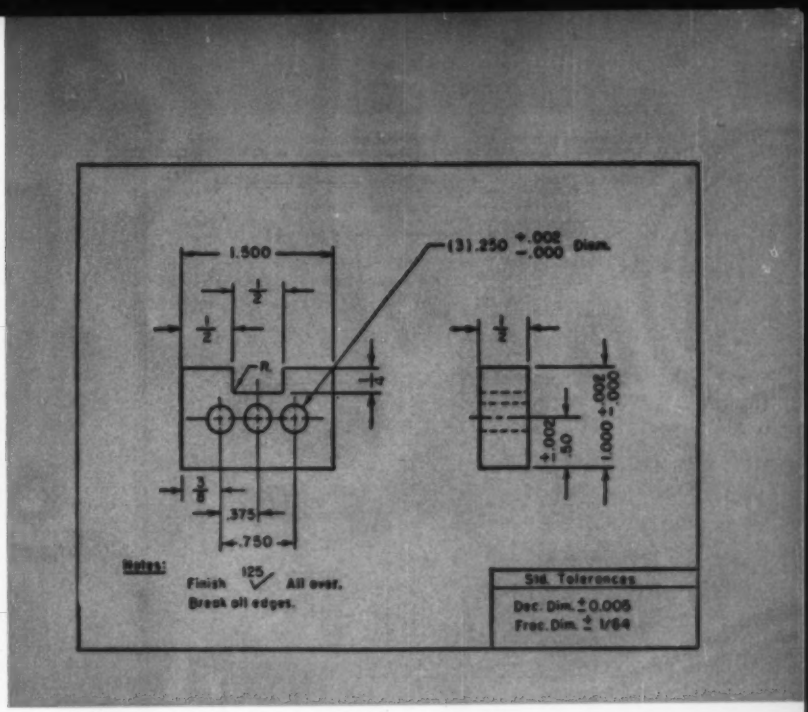
Three holes are delineated:

1. Do they have to be round? Can they be oval?
2. Can one end of each hole be 0.250-in. diam and the other end 0.252-in.?
3. The holes are shown perpendicular to some surfaces and parallel to others. Which is the governing specification and what is the tolerance? Must the holes be parallel to each other and, if so, to what tolerance?
4. The holes are shown located on a common center line. Is this necessary or can each hole be separately located within 0.50 ±0.002 of the lower surface of the piece? If the axis of each hole lies in a plane common to all three, what degree of precision is required and how is the plane defined?

The missing information concerns form of the features on the part. A survey will show that almost any drawing allows the same ambiguity of specification. Often this results in assembled hardware which fails to function properly. While design concepts are suspect, the real culprit is frequently the looseness of specifications on drawings. Conversely, many dollars are lost because shop or quality-control personnel assume specifications tighter than required.

Of course, the problem can be overcome by including complete specifications on each drawing.

The illustration at the right is a typical engineering drawing of a simple part. For many purposes, this drawing is adequate. However, the specifications given are too incomplete to assure interchangeability or operation with mating parts. The missing information is frequently assumed, leading to misunderstanding among designer, maker, and inspector. Many specifications, tolerances, and explanatory notes are needed to indicate exactly what the designer expects. When these requirements are repetitive, a realistic Shop Practice Standard can be developed to supplement the drawings. The advantages and application of such a standard, and how to set it up, are discussed in this article.



out of blueprint specifications and tolerances

However, this approach would have many undesirable effects. Drawings would be quadrupled in size and cluttered with specifications and definitions required for their interpretation. Drafting and checking costs would skyrocket.

Shop Practices: A much simpler and thoroughly practical solution lies in a standard known as a Shop Practice. This is a general specification that is complementary to all drawings prepared within the company. It contains standard specification data that would otherwise be missing, as in Fig. 1, or would have to be repeated on each drawing. For instance, every drawing showing two plane surfaces at right angles to each other would have to contain a definition of squareness and the squareness tolerance allowed for each pair of surfaces. In every case a Shop Practice eliminates need for a definition of squareness on the drawing. In most cases, Shop Practice makes it unnecessary to add squareness tolerances.

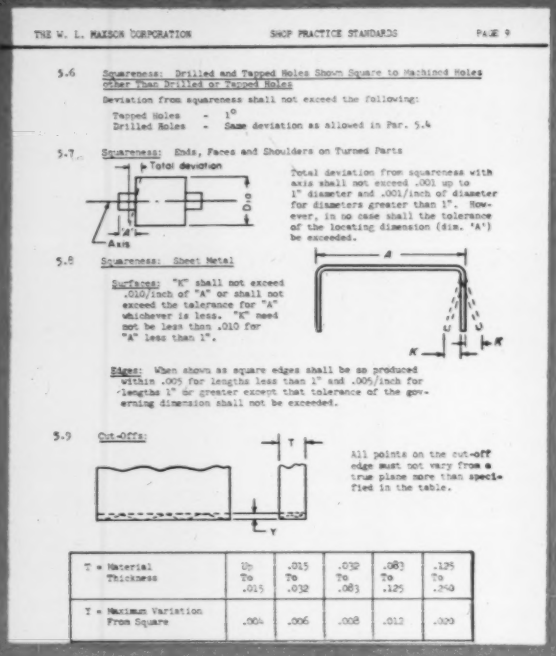
A successful Shop Practice within any company should be the best compromise between the designer's most frequently occurring specification and the normal ability of shop facilities to produce to this specification. In effect, the Shop Practice fills in the gaps on a drawing. It says, "In the absence of a designer's specification on the drawing, this is the minimum acceptable quality for the part." The Shop Practice must give the designer, draftsman, machinist, inspector, purchasing agent, and vendor a common semantic—a language as precise as the Latin used on a doctor's prescription. It must give assurance that:

1. The designer can specify his requirements accurately and in intelligible form.
2. The draftsman can use economical drafting practice.
3. The shop knows precisely what is specified.
4. The inspector knows the required quality and uses a uniform standard for acceptance.
5. The purchasing agent and vendor work to the same specification as is used internally within the originating company.

A well-conceived Shop Practice must include specifications in three general areas—those that are least specified and most often assumed. Whether they realize it or not, the designer and draftsman imply these specification in their drawings; shop personnel, inspectors, buyers, and vendors infer them. The three areas are:

1. Specification of form
2. Dimensioning practice and tolerances
3. Specialty definition

Specification of Form: Of all specifications on or off drawings, the specifications of form are most abused. These specifications, or their lack, plague the conscientious quality-control department in its



THE W. L. MAXSON CORPORATION SHOP PRACTICE STANDARDS PAGE 9

5.6 Squareness: Drilled and Tapped Holes Shown Square to Machined Holes other Than Drilled or Tapped Holes

Deviation from squareness shall not exceed the following:

Tapped Holes - 1°
Drilled Holes - Same deviation as allowed in Par. 5.4

5.7 Squareness: Ends, Faces and Shoulders on Turned Parts

Total deviation

Axis

Total deviation from squareness with axis shall not exceed .001 up to 1" diameter and .001/inch of diameter for diameters greater than 1". However, in no case shall the tolerance of the locating dimension (dim. 'A') be exceeded.

5.8 Squareness: Sheet Metal

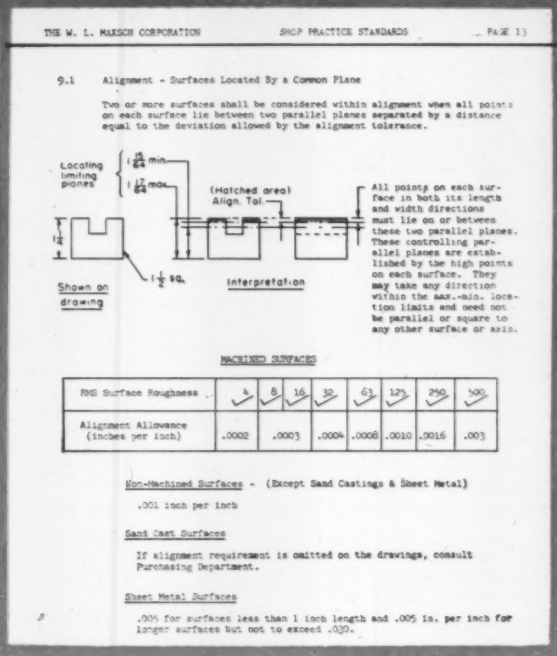
Surfaces: "K" shall not exceed .010/inch of "A" or shall not exceed the tolerance for "A" whichever is less. "K" need not be less than .010 for "A" less than 1".

Edges: When shown as square edges shall be so produced within .005 for lengths less than 1" and .005/inch for lengths 1" or greater except that tolerance of the governing dimension shall not be exceeded.

5.9 Cut-Offs:

All points on the cut-off edge must not vary from a true plane more than specified in the table.

T = Material Thickness	Up To .015	.015 To .032	.032 To .083	.083 To .125	.125 To .249
Y = Maximum Variation From Square	.004	.006	.008	.012	.020



THE W. L. MAXSON CORPORATION SHOP PRACTICE STANDARDS PAGE 13

9.1 Alignment - Surfaces Located By a Common Plane

Two or more surfaces shall be considered within alignment when all points on each surface lie between two parallel planes separated by a distance equal to the deviation allowed by the alignment tolerance.

Locating limiting planes

(Hatched area) Align. Tol.

All points on each surface in both its length and width directions must lie on or between these two parallel planes. These controlling parallel planes are established by the high points on each surface. They may take any direction within the max.-min. location limits and need not be parallel or square to any other surface or axis.

Shown on drawing

Interpretation

MACHINED SURFACES

RMS Surface Roughness	4	8	16	32	63	125	250	500
Alignment Allowance (inches per inch)	.0002	.0003	.0004	.0006	.0010	.0016	.003	

Non-Machined Surfaces - (Except Sand Castings & Sheet Metal)

.001 inch per inch

Sand Cast Surfaces

If alignment requirement is omitted on the drawings, consult Purchasing Department.

Sheet Metal Surfaces

.005 for surfaces less than 1 inch length and .005 in. per inch for longer surfaces but not to exceed .030.

efforts to check quality and cause malfunctions of assembled equipment. The cause for such malfunctions is difficult to locate and the cure is always expensive. When the W. L. Maxson Corp. realized the urgent need for a comprehensive Shop Practice of its own, the contributing groups quickly concluded that specifications of form were in greater demand, and because of the wide diversity of products manufactured, it would be necessary to prepare a Shop Practice with a very wide scope.

Because the Maxson Corp. produces precision computers, electronics gear, radar devices, and similar equipment, the Shop Practice includes form specifications which apply to gear plates, machined castings, sheet-metal parts, and items which are likely to be machined. Altogether, eleven specifications of form are expressed.

1. Flatness
2. Straightness
3. Parallelism
4. Squareness
5. Angularity
6. Roundness
7. Taper
8. Concentricity
9. Alignment
10. Edges and Corners
11. Surface Quality

Most of the specifications of form are self-expressive. However, it is surprising the different ways in which they can be interpreted, depending upon the point of view. The design engineer thinks first of function: He may specify surfaces in alignment because a sliding function is involved of a required precision and life expectancy. The shop considers fabrication: Which machine? Which set-up? Which tool must be used to produce the aligned surfaces within the tolerance and with maximum economy? These dissimilar attitudes produce subtle differences in interpretation of the alignment specification. The designer wants to specify a minimum acceptable quality; the shop tends to interpret a maximum acceptable quality.

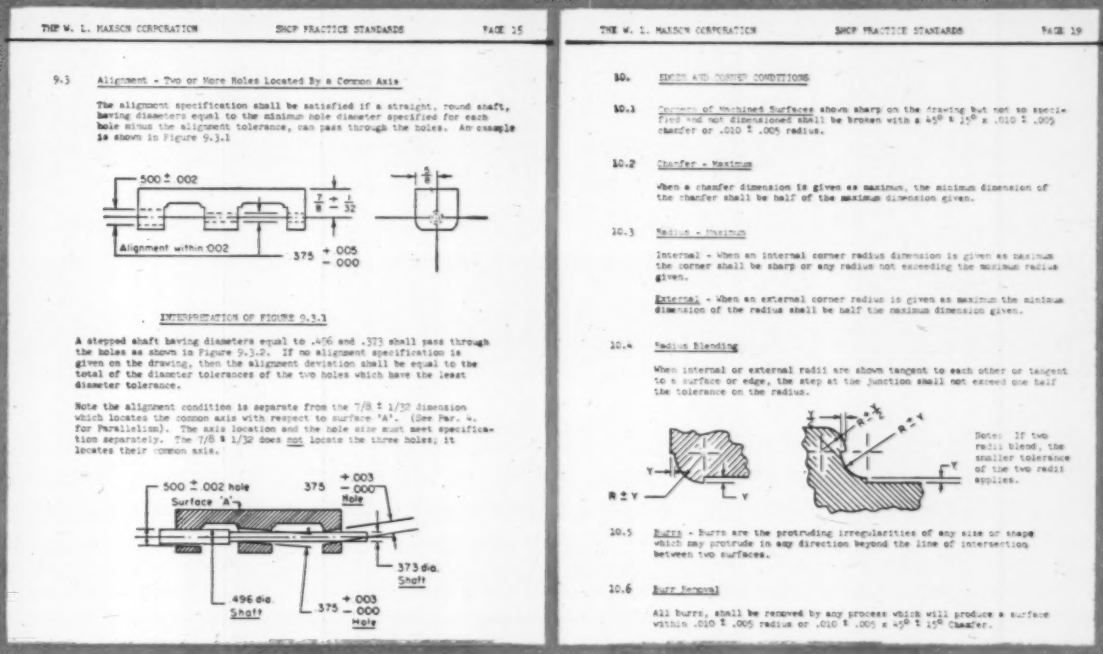
Each specification of form should at least encompass all of the commonly used features, such as:

1. Surfaces produced by machining, casting, and mill production of raw stock.
2. Surfaces produced by press-brake operations on sheet metal.
3. Threads and tapped holes.
4. Cylindrical surfaces, internal and external.
5. Drilled holes.
6. Slots and keyways.
7. Radii, chamfers, burrs, and undercuts.

The preparation of this area of the Shop Practice will be a guaranteed success if it is guided by four principles:

1. Stay within the limits of the company's operations. Do not try to prepare a single Shop Practice which will suit all the diverse needs of a sprawling industrial organization.
2. Include only specifications for frequently occurring items and then strike a good balance between designer's need and the shop's ability to produce.
3. The Shop Practice is not the last word in specifications; it is the average specification. If, in a single application, the designer decides the Shop Practice is too tight or too loose, he can override it by a note on the drawing. The test of a well-conceived Shop Practice is whether it coincides with the design engineer's specification most of the time.
4. Avoid methodizing, since it is decidedly not a Shop-Practice function. This is the arena of the Methods Department and belongs, if anywhere, in Manufacturing Specifications.

Since alignment specifications are not only least



THE W. L. MAXSON CORPORATION SHOP PRACTICE STANDARDS PAGE 15

9.3 Alignment - Two or More Holes Located By a Common Axis

The alignment specification shall be satisfied if a straight, round shaft, having diameters equal to the minimum hole diameter specified for each hole minus the alignment tolerance, can pass through the holes. An example is shown in Figure 9.3.1

INTERPRETATION OF FIGURE 9.3.1

A stepped shaft having diameters equal to .496 and .373 shall pass through the holes as shown in Figure 9.3.2. If no alignment specification is given on the drawing, then the alignment deviation shall be equal to the total of the diameter tolerances of the two holes which have the least diameter tolerance.

Note the alignment condition is separate from the 7/8 ± 1/32 dimension which locates the common axis with respect to surface 'A'. (See Par. 4. for Parallelism). The axis location and the hole size must meet specification separately. The 7/8 ± 1/32 does not locate the three holes; it locates their common axis.

THE W. L. MAXSON CORPORATION SHOP PRACTICE STANDARDS PAGE 19

10. EDGES AND CORNER CONDITIONS

10.1 Corners of Machined Surfaces shown sharp on the drawing but not so specified and not dimensioned shall be broken with a 45° ± 15° x .010 ± .005 chamfer or .010 ± .005 radius.

10.2 Chamfer - Maximum

When a chamfer dimension is given as maximum, the minimum dimension of the chamfer shall be half of the maximum dimension given.

10.3 Radius - Maximum

Internal - When an internal corner radius dimension is given as maximum the corner shall be sharp or any radius not exceeding the maximum radius given.

External - When an external corner radius is given as maximum the minimum dimension of the radius shall be half the maximum dimension given.

10.4 Radius Blending

When internal or external radii are shown tangent to each other or tangent to a surface or edge, the step at the junction shall not exceed one half the tolerance on the radius.

Note: If two radii blend, the smaller tolerance of the two radii applies.

10.5 Burrs - Burrs are the protruding irregularities of any size or shape which may protrude in any direction beyond the line of intersection between two surfaces.

10.6 Burr Removal

All burrs, shall be removed by any process which will produce a surface within .010 ± .005 radius or .010 ± .005 x 45° ± 15° Chamfer.

understood but most often misinterpreted, the Shop Practice should emphasize this specification and define it with crystal clarity. At Maxson, after considerable analysis, alignment was defined and specified for nine separate conditions:

1. Surfaces located by a common plane
2. Holes and surfaces located by a common plane
3. Two or more holes located by a common axis
4. Parallel holes located by a common center line
5. Slots and holes located by a common center line
6. Keyways or slots located by a common center line
7. Holes at an angle to each other and on a common center line
8. Angular surfaces
9. Countersunk surfaces

Dimensioning Practice and Tolerances: Shop Practice is the ideal vehicle to communicate the standard dimensioning practice and tolerances of the parent company. This section should contain specifications relating to:

1. Stock size
2. General tolerances
3. Tolerances for castings and forgings
4. Holes equally spaced on a circle
5. Holes equally spaced linearly
6. Drilled-hole tolerances

Again, careful study must precede publication because, unless the designer notes differently, the Shop Practice will apply. For instance, if a tolerance of ±0.005 is standard for decimal dimensions, most decimal dimensions will be so specified. The designer will specify tighter tolerances but rarely will a looser tolerance be found. This is disappointing because probability alone dictates that tolerances like ±0.007, ±0.009, and ±0.012 should occur much more frequently than they do. In many files it would be necessary to search all day to find a single tolerance of ±0.007 or ±0.011. A statistical plot will show huge peaks at ±0.002, ±0.005, and ±1/64, with rock-bottom valleys in between.

The creation of a standard tolerance may become a psychological stumbling block to the specifying designer. Instead of thinking in terms of the widest tolerance a dimension can have without compromising design functions, he may think only of the standard tolerance that can be specified.

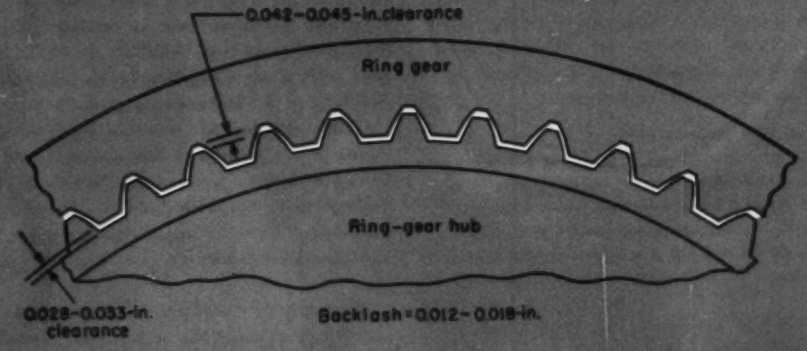
Specialty Definitions: The scope of this feature of the Shop Practice is completely determined by the company's products. Within this area are all of those notes and specifications frequently required by the individual firm but which do not fit readily into the two preceding sections. These may be concerned with inspection methods, burr removal, cleaning, polishing, plating, or painting. Materials and the methods of testing and qualifying them might be included. Generally speaking, this section will include the specifications that are closely allied with the company's internal procedures, products, and processes, rather than the semistandard material in the two earlier sections.

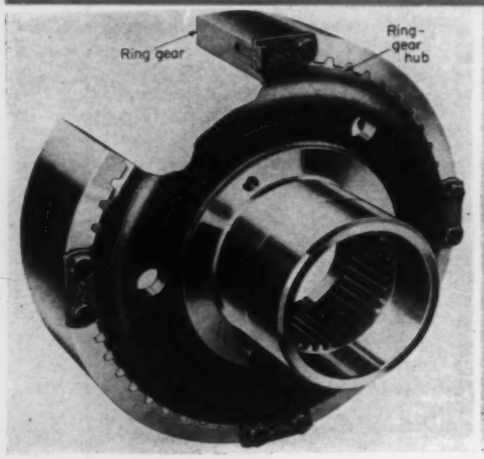
Editor's Note

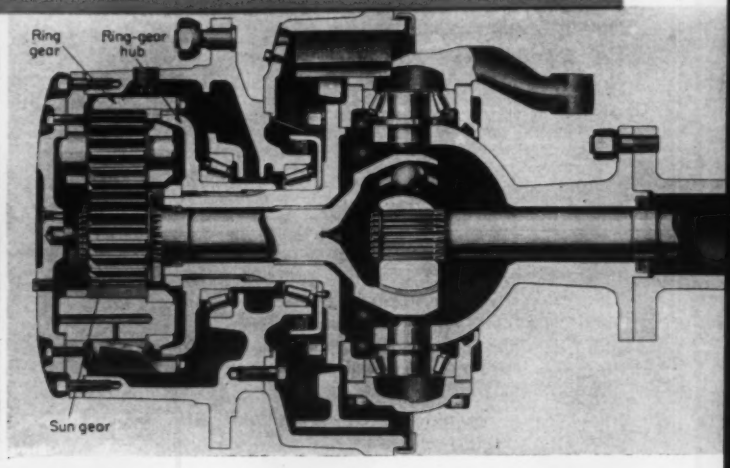
A large part of the material contained in a Shop Practice is concerned with definitions of geometric form and tolerances for deviations from theoretical form. This is a relatively little-understood area of the subject of dimensions and tolerances and should be carefully considered if a Shop Practice Standard is to be formulated. The subject was thoroughly covered by Fred Spalding in the May 15, 1958, issue of Machine Design, along with a discussion of the new ASA standard on dimensions and tolerances.

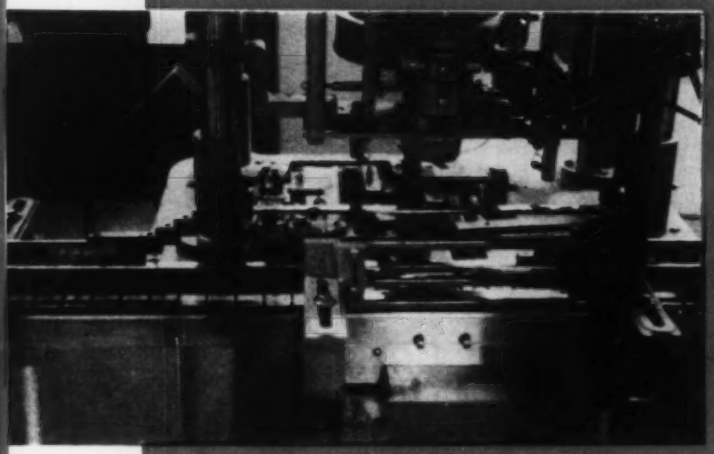
scanning the field for *ideas*

Floating-gear design of planetary train assures uniform distribution of operating tooth loads. In this design, developed by Timken-Detroit Axle Div. of Rockwell Spring and Axle, both the sun and the ring gears are free to move radially to conform to the action of the rigidly mounted planetary pinions. The ring gear and its hub are in two separate pieces; the ring gear is splined to the ring-gear hub, but floats radially, transferring only torsional loads. The sun gear is similarly mounted on its shaft. The design equalizes distribution of stresses among the planetary gears.

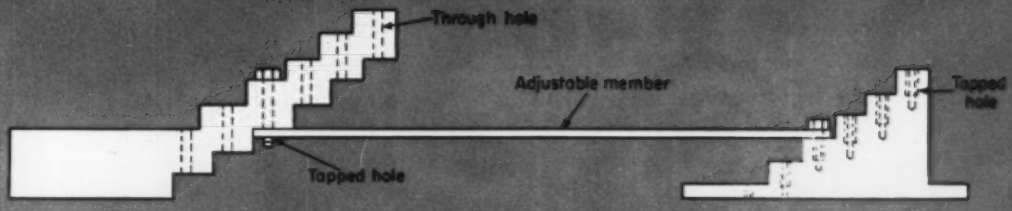




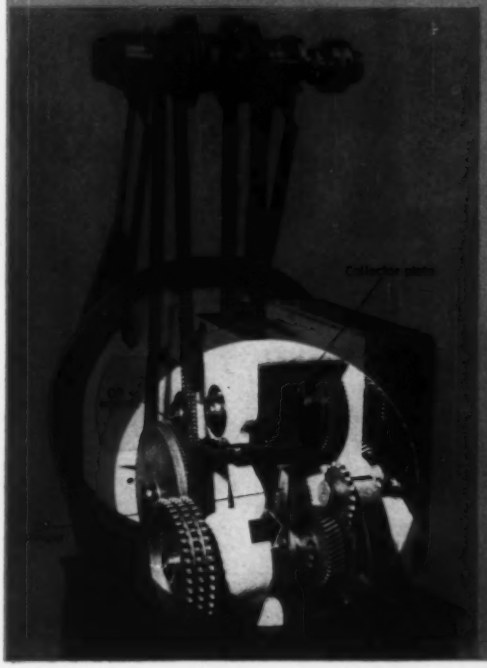


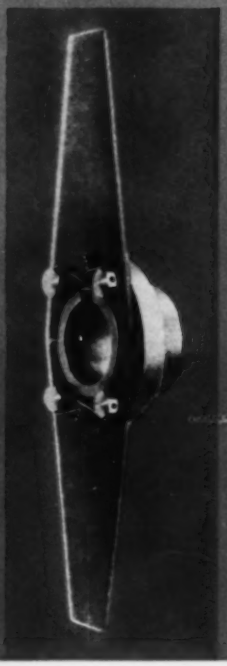


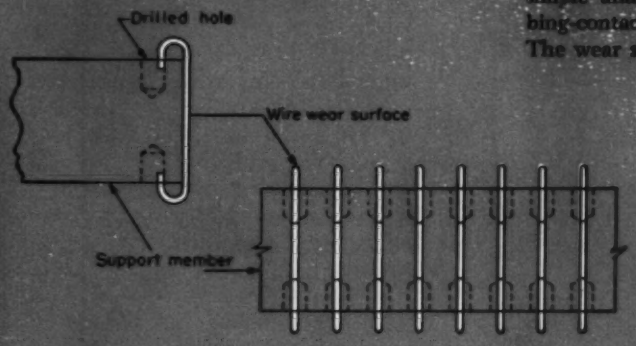
Stepped support mounts for rod or bar beam elements simplify height or positioning adjustments in machine structures to accommodate varying operating requirements. The adjustable beam member is tapped at one end and drilled for a screw-clearance hole at the other. The tapped end is fastened to the underside of the step on one of the supports while the other end is fastened on top of the matching step on the other support. The stepped supports are made in pairs, cut to shape and finished to the required precision. The design was developed by Resina Automatic Machinery Co. Inc.



Paddle-wheel oiling of inaccessible rotating members provides lubrication without use of a pump and distribution lines. The paddle-wheel oil slinger is mounted on a high-speed rotating shaft. During each rotation, the paddles dip into an oil pan and the oil is then thrown off by centrifugal force. A portion of the oil strikes a collector plate and runs down into an open trough which carries the oil to the required place. The design was developed by Brown & Sharpe Mfg. Co. for use in the oiling system of an automatic screw machine.



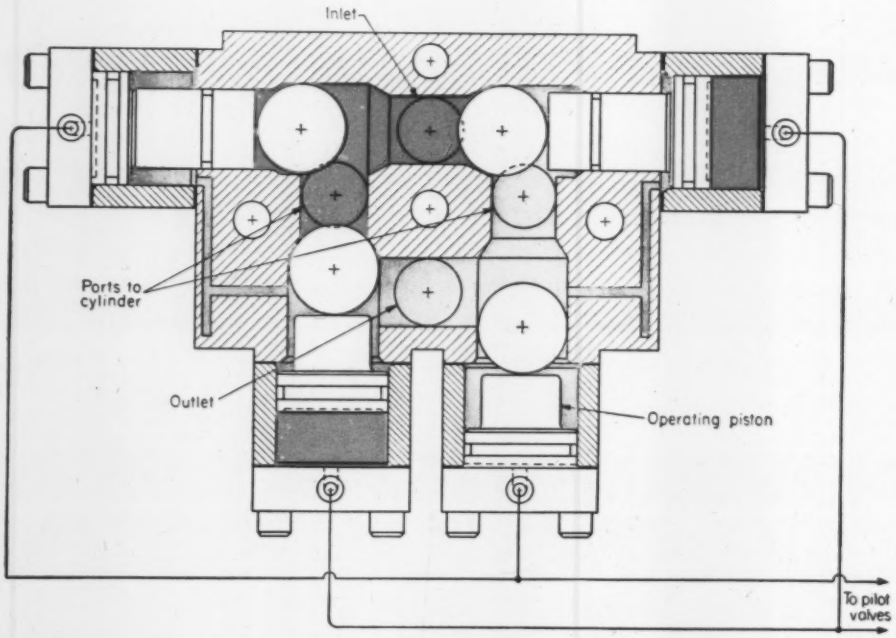


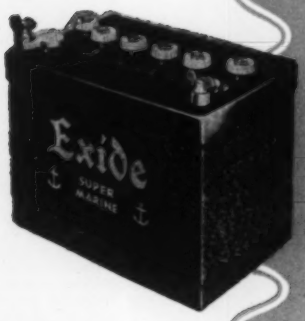


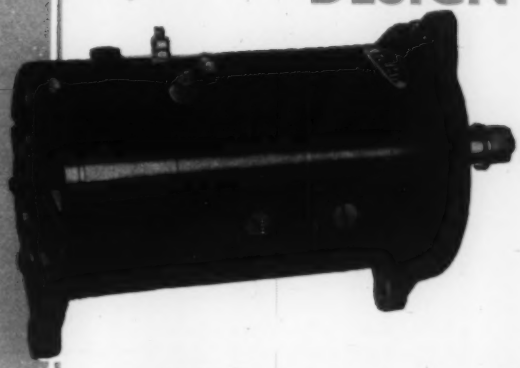
Multiple-wire wear surface offers a simple and effective low-cost solution to rubbing-contact problems in machine members. The wear surface is provided by a multiplicity of simple wire forms that are bent into a C-shape and are retained in place by clipping the ends into holes in the supporting member. Developed by Elgin Mfg. Co. for use in a high-speed wrapping machine, the wear surfaces act as guides for packages being lifted to the wrapping station.

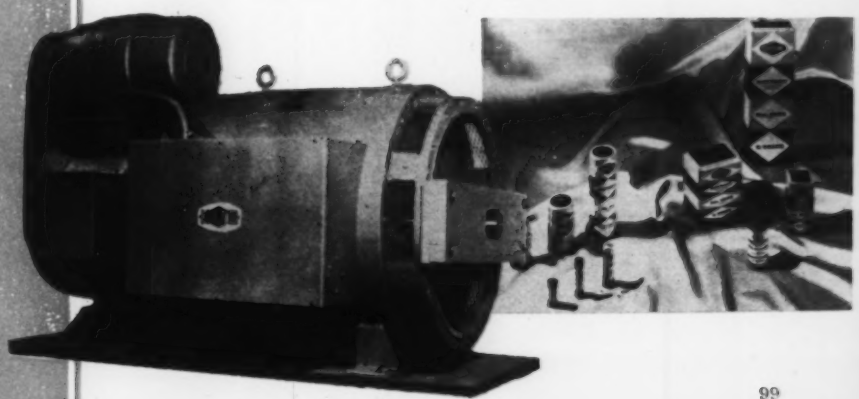
Multiple ball valves are employed in a unique spoolless hydraulic-valve design to provide automatic "dumping" under over-load conditions. Four individual ball valves are used in the design. Each unit is closed by an operating piston and opened by line pressure on the ball face when pilot pressure is removed from the piston.

The area of the operating-piston face is a multiple of the effective area of the ball as measured in the closed position. Thus, the valve ball and its piston will be forced back to permit dumping when the total pressure on the ball face exceeds that on the piston. The design was developed by Almar Hydraulic Valve Co.









DESIGN MANUAL

Electronic and Electric

POWER SUPPLIES

Selection, specification, and application data on

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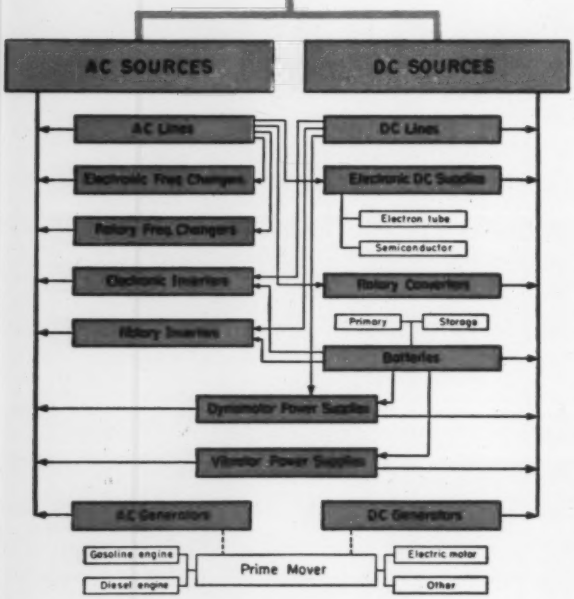
Electronic and Electric POWER

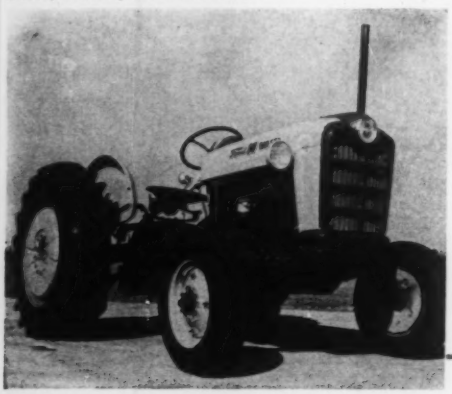


Today, ac or dc electric power is required in the design of practically every type of machine or powered equipment. Whenever possible, electrically powered equipment should be designed to operate directly on ac or dc commercial electric lines. The savings in weight, size, and cost are obvious.

However, many products often require one or more special ac or dc voltages; for example, radios, TV sets, electronic computers, and test instruments. And, of course, machines such as farm tractors, automobiles, missiles, or boats simply cannot be "plugged-in" an electrical outlet. Here, special-purpose power supplies or power-conversion units are required—electronic power supplies, frequency changers, motor or engine-driven generators, vibrators, dynamotors, batteries. These electric power packages can be built-in or located remotely, depending on space, weight, and heating limitations.

Selection of the proper electric power supply for a given application requires careful

Photo, courtesy Ford Motor Co.

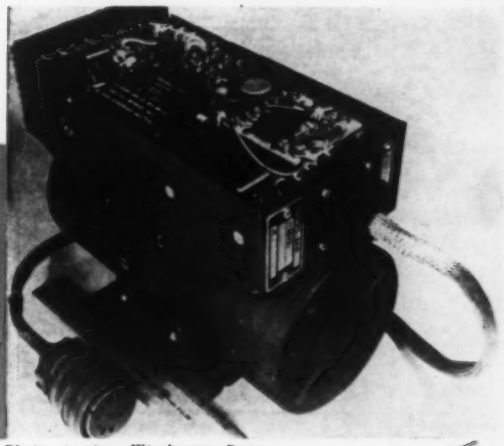


Normal starting-load requirements for this new diesel-powered farm tractor are met by a 12-v generator-battery electrical system. Under extremely cold environmental conditions, optional manifold preheaters or an ether cell can be used as a starting aid.

Photo, courtesy Tri Phi Inc.

Flashlight batteries supply electric power to transistorized portable phonograph. Four size D batteries are used to operate both the turntable motor and the amplifier.

SUPPLIES

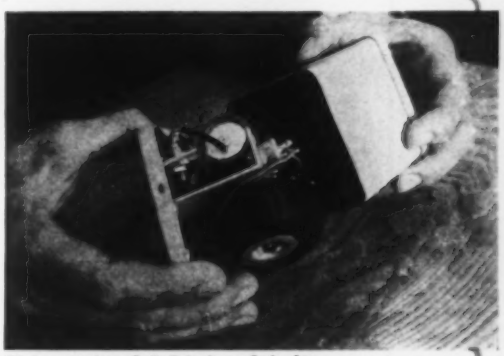


Photo, courtesy Wincharger Corp.

Closely regulated dynamotor power supply built to withstand shocks of 60 g and operate at altitudes up to 65,000 ft. Designed to operate on a 24 to 30 v dc input, the unit provides three output voltages: 300 v dc, 22.6 v dc, and 6.6 v ac at 600 cps.

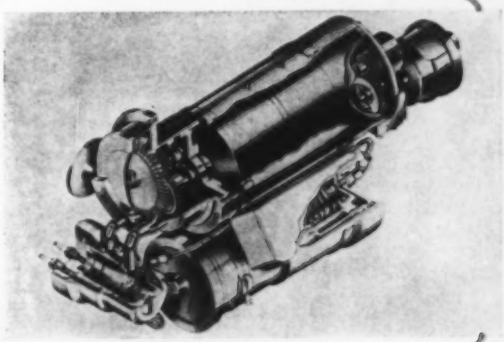
evaluation of each available type, from the standpoints of power capabilities and design limitations. A thorough comparison of physical and electrical characteristics of the various types of power sources will usually point up only two or three really suitable possibilities. Final choice is dictated by voltage and current requirements, environmental conditions in service, space and weight considerations, cooling problems, whether standard electric lines can be connected, and of course, cost.

Once the decision has been made to incorporate an electric power supply in a design, two important steps must be taken by the designer if he plans to buy either a special or off-the-shelf unit: 1. The power supply and its intended application must be specified as accurately and completely as possible. 2. When applied, the power supply must be properly integrated into the equipment from a mechanical and an electrical standpoint. The following articles are written to help the designer fully satisfy these two objectives.



Photo, courtesy Bell Telephone Lab. Inc.

Transistorized dc-to-dc power supply designed for a 24-v battery input. This completely static, 30-w unit offers the design advantages of long life and high power-conversion efficiency. Power conversion units of this type can also change dc to ac.

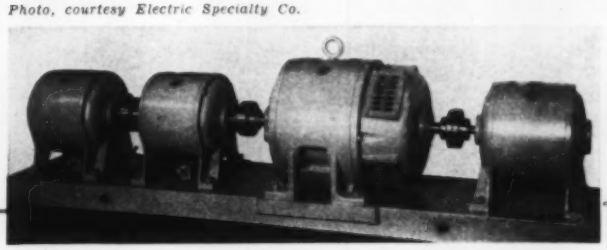


Photo, courtesy General Electric Co.

Missile or manned-aircraft auxiliary power source which can supply electric power, hydraulic power, or both with outputs of 1.5 to 10 hp. Powered by ethylene oxide or other monopropellant fuels, the unit can be designed to operate from 29 to 347 sec, depending on application requirements. Designed with two alternators, one can provide 1000 w of 400-cycle, 115-v, three-phase power and the other 100 w of 2400-cycle, 115-v, single-phase power.

Motor-generator electric power source with an adjustable phase-angle output. Developed for special equipment-testing work, the unit is composed of three single-phase, separately-excited inductor alternators. The stators of two alternators can be adjusted through 360 electrical degrees to give any desired phase angle between the three alternators.

Photo, courtesy Electric Specialty Co.



Specifying and applying

ELECTRONIC POWER

By **DONALD W. TANNER**, Section Manager
JOHN P. LEON, Senior Project Engineer
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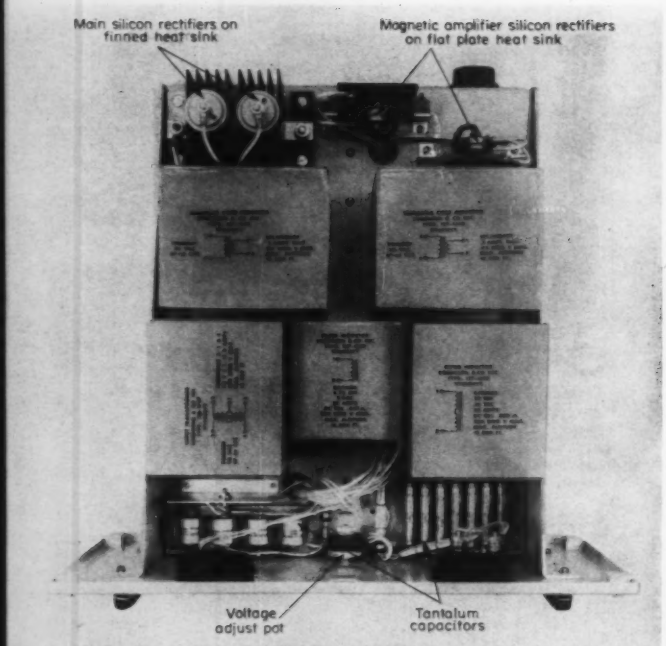
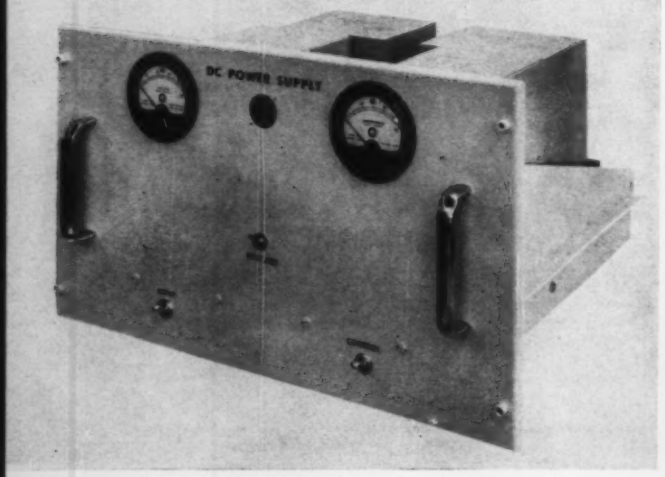
Sorensen and Co. Inc., South Norwalk, Conn.


Main silicon rectifiers on finned heat sink
Magnetic amplifier silicon rectifiers on flat plate heat sink
Voltage adjust pot
Tantalum capacitors

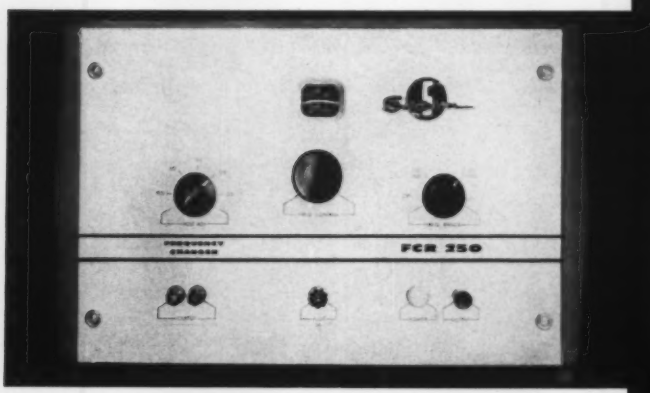


Proper and reliable operation of electronic equipment depends heavily on the output characteristics of the power supply. Accuracy and completeness of information in specifying an electronic power supply is often a key factor in the successful operation of a design. Data on input and output power are always important, but regulation, ripple, transient response, temperature stability, and other factors can be equally critical requirements.

ELECTRONIC equipment, such as TV sets, radios, and computers, often requires a number of dc and ac voltages other than that available from standard electric power lines. Many times in industrial machines, ships, airplanes, etc., electrical power and control components, such as electric motors, solenoids, and relays, require special

Fig. 1—Left—Dc power supply for the Atlas missile program. Operated on 115-v, 60-cycle ac, the output power rating is 26 to 30 dc at 20 amp with ± 5 per cent regulation. Reference source is a power Zener diode. Tantalum capacitors are used for reliability and long life

Fig. 2—Below—Inverter-type frequency-changer power supply. This electronic unit supplies 250 v-amp at 115-v output over a frequency range of 320 to 1000 cps. Input power is 50 or 60-cycle, 115-v ac



SUPPLIES

Electron-tube and semiconductor types
Environmental and mechanical factors
Electrical operating characteristics
Methods of regulation
Electronic equipment applications

voltages and frequencies. One answer is the electronic power supply, which is really an electrical power-conversion device.

Electronic power supplies operate on ac or dc power lines, ac and dc generators, or batteries. When an electronic power supply produces primarily dc output voltages, it is known as a *dc power supply*, Fig. 1, whether it is energized by ac or dc. A dc power supply will sometimes also provide a source of low-voltage ac power to heat electronic-tube filaments.

An electronic-type power supply which operates on ac and produces an ac output of a different frequency is known as a *frequency changer*, Fig. 2. Sometimes these frequency changers are called inverters, but this term is more properly reserved for power supplies which change dc power to ac.

Physical Considerations: Environmental factors should be an early design consideration and included in the power-supply specifications. Usually environmental conditions other than ambient temperature are not too important, except in military applications. These can best be specified by calling for the military specification for a particular test, such as humidity, vibration, altitude, shock, etc.

Special features, such as meters, switches, circuit-protection devices, connectors, etc., should be specified.

Most of the mechanical and physical design considerations are about the same for dc power supplies, regulators, or frequency changers. If known initially, the designer can specify the type of mounting, method of cooling, location of controls and meters, types and thickness of materials, finishes, etc. Life, reliability, size, shape, and weight of a power supply are often important, too.

However, many of these factors cannot be determined with any degree of accuracy until all of the electrical power output and performance demands are satisfied. A checklist of most of the physical and electrical specifications are given in Table 1.

▶ DC Power Supplies

This section discusses the various factors that should be considered when specifying a special or off-the-shelf dc electronic power supply. Many of these specifications also apply to frequency changers.

Table 1—Specification Checklist for Electronic Power Supplies

1. **Output Voltage and Frequency**
   a. Fixed
   b. Adjustable
   c. Ac or dc
2. **Output Current**
   a. Maximum
   b. Minimum
3. **Input Voltage**
   a. Variation
   b. Frequency
   c. Single or polyphase
4. **Regulation**
   a. Line
   b. Load
   c. Line and load
   d. Plus and minus and total
5. **Ripple or Distortion**
   a. Rms value
   b. Peak-to-peak value
6. **Transient Response**
   a. Maximum excursion
   b. Response time
   c. Output impedance
7. **Temperature Stability**
   a. Change vs. temperature range
   b. Change vs. time
8. **Thermal Drift**
   a. Initial
   b. Total warm-up time
9. **Long-Time Stability**
   a. Change vs. time
10. **Ambient Temperature**
    a. Maximum
    b. Minimum
11. **Environmental Conditions**
    a. Humidity
    b. Altitude
    c. Shock
    d. Vibration
    e. MIL specs
12. **Meters**
    a. Size
    b. Accuracy
13. **Switches**
14. **Protective Devices**
    a. Fuses
    b. Thermal or magnetic breakers
15. **Pilot Lights**
16. **Terminals**
    a. Line cords
    b. Binding posts
    c. Terminal strips
17. **Mechanical Construction**
    a. Bench mounted
    b. Rack mounted
    c. Built-in
    d. Conventional or fan cooled

Output Power: The first data to determine, when specifying a dc electronic power supply, are output voltage and current requirements. Is the voltage fixed or adjustable? The tolerance on a fixed voltage is sometimes called setting accuracy and must be specified. This is particularly true for unregulated or magnetic-type line-regulated supplies where no inexpensive means of adjustment is available. Normal tolerances, principally in the turns ratio of transformers, will result in variations of several per cent around nominal value. Ambient temperature change and thermal drift will also cause appreciable variations. This tolerance around the fixed value must be specified at some condition of input voltage and frequency, load current, ambient temperature, and length of time after turning unit on or warm-up period.

If voltage is adjustable, the adjustment range in volts or percentage of either side of nominal should be specified. Must adjustment be continuous or can it be in steps? If output is continuously adjustable, what is the setting accuracy or resolution?

Current, except in current regulators where all the statements about voltage also apply to current, is easier to specify than voltage provided the maximum value of current required is known. What often happens when special power supplies are incorporated in electronic equipment where numerous loads are energized by each of several voltages, is that total load is not known when the power supplies are ordered. Often, this cannot be helped because if the equipment designer waits until he is sure of the total load, he leaves little time for the supplier to design and build the power supply. The answer to this problem is, of course, to ask initially for more current than needed. It is easier to redesign an electronic power supply for less current for cost-reduction purposes after the maximum value is finally established than to find ways of increasing current in an existing design.

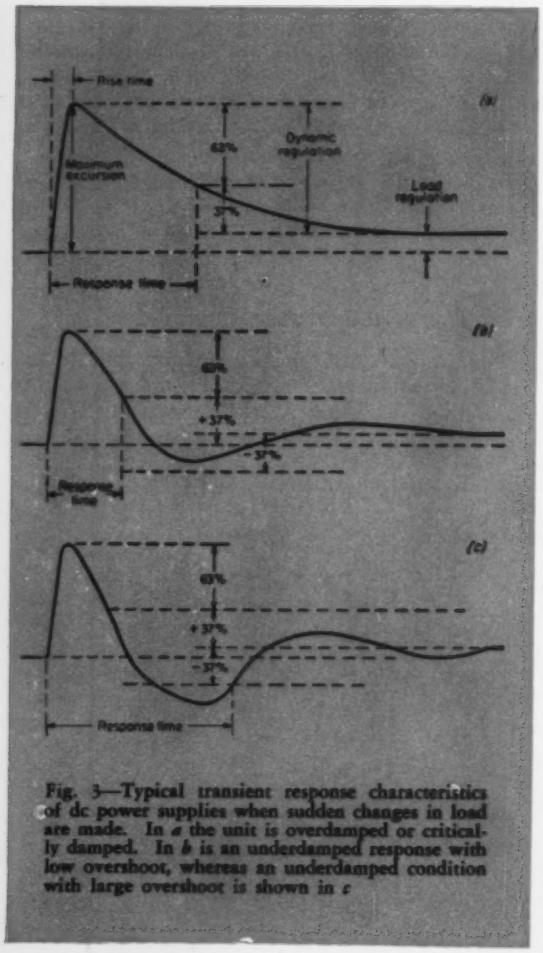


Fig. 3—Typical transient response characteristics of dc power supplies when sudden changes in load are made. In *a* the unit is overdamped or critically damped. In *b* is an underdamped response with low overshoot, whereas an underdamped condition with large overshoot is shown in *c*

Minimum current at which the power supply will be expected to operate should also be specified. If this current is appreciable, built-in bleeder current in the power supply can be lowered, reducing cost and size of power supply. However, if there is a chance that part or all of the minimum load will be accidentally removed and a higher-than-normal voltage would result which would cause damage to the equipment or power supply, this fact should be clearly specified.

Duty cycle and repetition rate of the load current should be specified unless the power supply is rated for continuous duty at any load. Specify conditions where the load goes on and off in some periodic cycle. For example, a unit which has to carry full load for only 5 min in every hour and no load the other 55 min would be cheaper than one which has to carry full load continuously.

Input Power: Three important input-power requirements which must be specified are input voltage, phase, and frequency. The frequency is determined by what is available where the equipment is to be used. If there is a choice, selection of higher frequencies, such as 400 cps instead of 60, will reduce power-supply size and weight. Whether frequency is fixed, as on commercial power lines, or variable, as in most 400-cycle military applications, must be specified. In some cases, operation at two different fixed frequencies, such as 50 and 60 cps, may be requested.

Three-phase power is more efficient for ripple reduction and rectification, but it requires the use of more rectifiers and transformer windings. It is seldom economical to specify three-phase below 1 kw of output power. From 1 to 5 kw the most economical phase depends on individual requirements. Above 5 kw, single phase is seldom used. When there are a number of power supplies, many of which should be single phase on an individual basis, but the total power involved is large, three-phase power is recommended with provision that individual supplies can be single-phase if the unbalance in input current between phases is restricted. Large single-phase loads in other parts of the total system can be compensated for by unbalancing power-supply loads. Unbalance in total system load will result in phase unbalance in input voltage. This condition causes increased ripple in dc output. If three-phase rectification is being used, phase unbalance if more than 1 per cent should be specified.

Single-phase units with input currents less than 30 amp are usually designed for 115 v input. Above 30 amp input, 208 or 230 v ac is usually the nominal input value. Three-phase units are rated at 120/208 v ac unless input-current requirements are high; then 240/416 v ac can be specified. The variations around the input must also be given, since this is related to regulation accuracy. If the input range is too wide, it may increase the costs of the power supply appreciably.

The other input characteristics, such as current, efficiency, power factor and volt-ampere efficiency, are determined by the output power and the performance specifications. Often, however, they cannot be closely specified early in design. It should be noted, however, that the power factor of magnetic-amplifier regulated supplies is poor, sometimes as low as 50 per cent lagging. Power-factor correction can be used, but because of nonsinusoidal waveshapes of the current, correction to 100 per cent is not possible. Power-factor correction is a system problem, not a power-supply problem, particularly if the system load is much larger than the power-supply load. For example, increasing the power factor from 55 to 75 per cent on a power supply might only raise the system power factor from 70 to 71 per cent.

Ripple and Transient Response: Ripple should be specified either as a percentage of the dc value or as a value in volts or millivolts independent of the dc value. Normally ripple is expressed as an rms value, but if spikes in ripple can cause circuit trouble as in computers, it should be expressed as either a peak or peak-to-peak value.

Transient response is the most difficult of the performance requirements to specify. With vacuum-tube regulators this is usually expressed as output impedance (to sinusoidal load changes). This requires running tests over a wide frequency range of load current variation, and for low-voltage, high-current supplies, this may be difficult to perform. Results are also affected by the amplitude of load-current change and the operating point at which tests are taken. There is also some doubt as to the practical value of the results, since sinusoidal load changes are not often encountered in practice. Output impedance specifications for square-wave pulse loads would be of more practical value since this type of loading is often encountered.

The most practical way to specify transient response, however, is to define what happens when a step change of line or load is suddenly applied. This is known as the transient or surge response characteristic and consists of the amplitude of the voltage excursion and the time that it takes for the voltage to recover.

Fig. 3*a* shows what happens when a sudden load change is made under over-damped or critically damped conditions, and Fig. 3*b* and *c* illustrate what happens when underdamped conditions occur for two amplitudes of overshoot.

It is obvious that the maximum excursion is the difference between the peak voltage obtained and the

GLOSSARY OF ELECTRONIC POWER SUPPLY TERMS

Adjustment range—Output voltage range over which power supply can be adjusted at nominal values of input line and load.

Bleeder current—Current drawn through resistor placed across output of unit to discharge capacitors when unit is turned off, i.e., bleed charge out of capacitor. Also, in many supplies this current is made higher than required for bleeding to improve no-load regulation.

Distortion—That part of the ac waveform caused by frequencies other than fundamental. Distortion is measured as a comparison between the output voltage and the output voltage with that part contributed by the fundamental eliminated. It is usually specified in decibels or per cent.

Drift—Deviation from a specific value as related to time. See *Stability*.

Duty cycle—On and off times of load current.

Efficiency—Ratio of output power to input power.

Efficiency, volt-ampere—Ratio of output power to input volt-amperes. This is the product of efficiency and power factor.

Excursion, maximum — Largest peak value, either positive or negative, measured from the initial value. This is caused by a transient and is expressed in either volts or per cent. See *Response time*.

Output impedance—Impedance presented by the unit to the load, looking into the unit from the load. The ratio between a change in output voltage for a given load change and the magnitude of the load change. This impedance should be specified as a dc value or as a dc value plus an ac value over a certain frequency range and measured in accordance with the IRE Standard published in the *IRE Proceedings*, January, 1951.

Power factor—Ratio of input watts to input volts times input amperes.

Phase unbalance—Ratio of difference of highest and lowest input voltages in a three-phase system to the average voltage.

Pulse load—Load which goes on and off at a rapid rate. On and off times may be equal or unequal.

Recovery time—Period of time from the initiation of a transient to the point where the output has returned to within its regulation limits.

Resolution—Accuracy at which voltage can be set as affected by number of turns on potentiometer or variable autotransformer.

Response time—Time required from the initiation of a transient to point where output has recovered 63.2 per cent from its maximum excursion. See *Excursion, maximum*.

Regulation—Change of one of the output parameters (voltage, frequency, etc.) resulting from a change of one or more of the unit variables, within the unit specifications or for prescribed increments. All other variables to be kept constant.

Ripple—That portion of the output voltage harmonically related in frequency to the input voltage and arising solely from the input voltage. Normally expressed in peak-to-peak or rms volts or per cent. Per cent (rms) ripple is the ratio of the effective (rms) value of the ripple voltage to the average value of the total voltage expressed in per cent.

Rise time—Time from start of transient to time at which peak deviation occurs. Also, time for load current or input voltage to change on step change or pulse load.

Setting accuracy—Same as *Resolution*. Sometimes also the tolerance on voltage of nonadjustable supply.

Stability—The change in one of the output parameters (voltage, frequency, etc.) over a period of time caused by the aging of circuit components; all variables (temperature, line voltage, etc.) kept constant.

Step change—An instantaneous but relatively permanent increase or decrease in load current or input voltage. Since nothing is truly instantaneous, there is a rise time involved.

Temperature coefficient—Change in output voltage over the ambient temperature range of the unit expressed in per cent per degree.

Thermal drift—Amount of output drift which occurs between the initial delay time and the time it takes for all thermal effects to stop.

Transient response — Output voltage change with time when a step change of line or load is made. Also known as *surge response*.

Warm-up time initial—Interval between the time of application of input power to unit and the time at which unit is supplying regulated power at rated output voltage. Also known as *delay time*.

Warm-up time, total—Interval between the time of application of input power to unit and time after which unit must meet its stability specification.

initial value. The total rise time, or the initial rate of rise, can also be specified if it is considered necessary.

Dynamic regulation is another method of specifying maximum excursion. This is sometimes not so well understood unless stated whether this is the difference between maximum excursion and steady-state regulation or whether it is another term for maximum excursion.

Response to pulse loads must also be considered. Pulse amplitude, pulse-repetition rate and, for other than square-wave pulses, the on and off time must be specified. If the pulse rate is slow and the on and off times are several times longer than response time, pulses may be treated in the same manner as a step change.

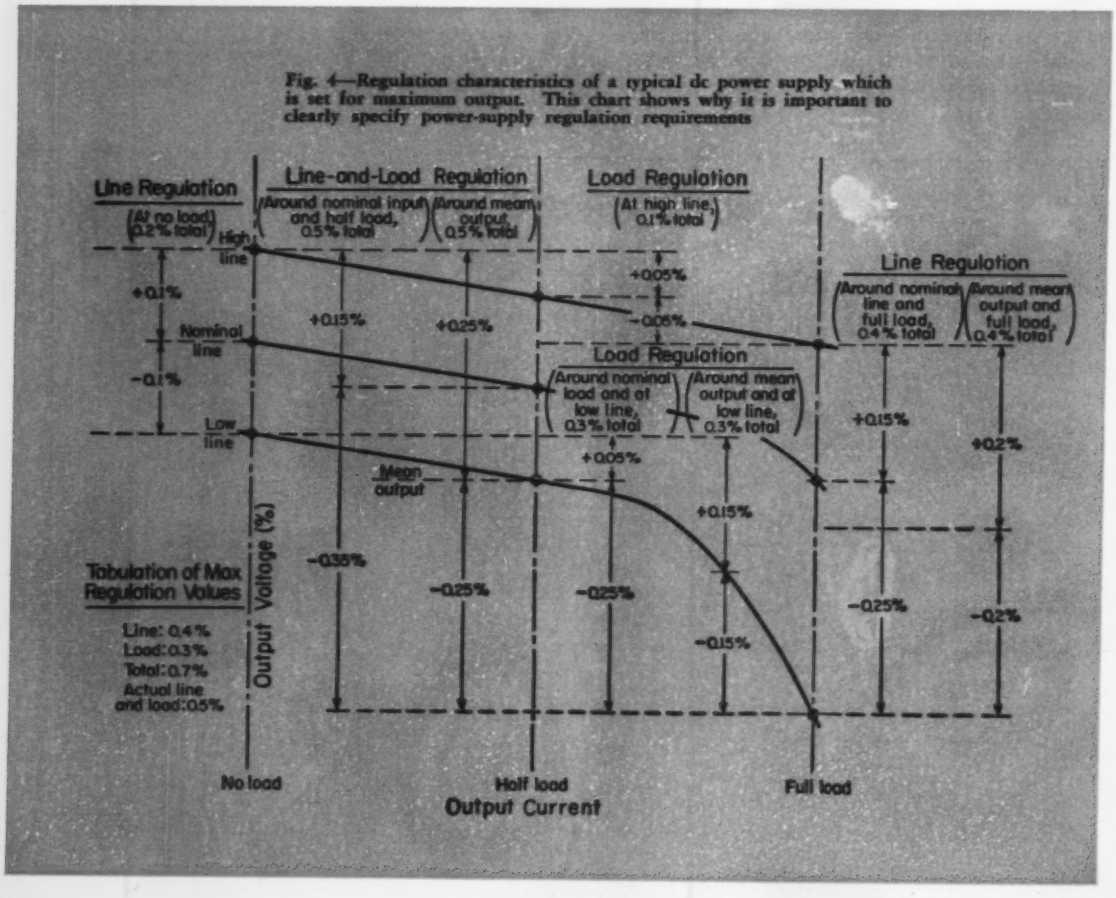
If the pulse rate is fast and the on time is much shorter than the rise time, then ripple will be induced in the output voltage at same frequency as pulse. The specification should define the peak-to-peak value of this ripple. The output impedance in this case is determined by capacitance across the output. If the pulse rate is intermediate in speed, peculiar looking output-voltage transients may result, depending on what part of response cycle the pulse goes on and off.

Stability and Drift: Aside from changes in the line, load or frequency, output voltage will also change because of two other factors—temperature and time. Characteristics of various circuit elements vary with temperature, changing the output voltage of unit. Output voltage of voltage reference elements, such as Zener diodes, also changes with temperature. In unregulated supplies, the resistance of transformer and choke windings changes. Compensation circuits may be added to reduce these effects.

Temperature stability should be expressed as a change in output voltage or percentage for a given change in ambient temperature. It can also be expressed as a temperature coefficient in volts per degree. This is a somewhat restrictive specification since it implies, unless stated as an average, that the rate of change must never exceed this coefficient. Since the actual characteristic may be nonlinear, this will result in an over-all change less than desired, which may cost money.

Temperature range over which temperature-stability specification holds should, if possible, be made narrower than the full operating temperature range. For example, electronic ground equipment designed to operate over a wide range of temperatures from arctic to tropical zones will never be subjected to the full temperature range in any one period of operation.

Fig. 4—Regulation characteristics of a typical dc power supply which is set for maximum output. This chart shows why it is important to clearly specify power-supply regulation requirements



Change of output voltage with respect to time is divided into several periods, the first of which is not really a drift. Initial warm-up time, caused principally by tube filaments, results in an output not even approaching final value for a short time. If no tubes are present, initial delays are short, consisting mostly of capacitor-charging time.

The next stage is thermal drift which is caused by the changing temperature of components. This is related to ambient temperature change and may last on large units for many hours. Since a large part of the change occurs fairly rapidly, it is advantageous to allow a warm-up period of 5 to 60 minutes before calling on power supply to meet drift specification.

After the thermal warm-up period is completed, further drift occurs because of aging of components causing permanent changes in their characteristics. This is also to some extent still a thermal effect since aging of some components, such as selenium rectifiers, is at least partially caused by high temperatures.

Regulation: This performance specification, despite its apparent simplicity, causes a lot of confusion. This is caused by two factors: 1. What does *plus and minus* mean? 2. What does *line and load* and *line or load* mean?

Regulation is usually expressed as plus or minus a certain percentage or voltage. For example, a line-regulation value of ±0.2 per cent means there is a 4 per cent variation between the highest and lowest output voltage as input voltage is varied. This is called total variation and is equal to twice the plus-and-minus value. With the output voltage set at a given value (with the input at some unknown value), it does not mean that the output will not vary more than 0.2 per cent in either direction when the input varies. Also, if the input voltage varies, for example, from 105 to 125, one cannot set the input at 115 v and necessarily expect the output variation to be ±0.2 per cent as line voltage goes up or down. Most of the variation can occur in one direction. This is the nature of regulating devices. At full load, the tendency is for most of the change to occur from nominal to low line and at light load, from nominal to high line. The ±0.2 per cent applies around the mean output voltage. It is usually desirable to specify line regulation with load held fixed and load regulation with line held fixed. In other cases, regulation for both line and load changes together is desirable. Methods of specifying which method is best are vague. The statement "line or load" appears to apply to the first case and "line and load" to the last, but in many cases designers specifying "line or load" think they are getting "line and load." It is best to clearly state this by the use of the words combined or separately.

Fig. 4 shows curves of output voltage versus load current for high, nominal, and low line voltage for a power supply set at the high end of its adjustment range. At full load the load regulation around nominal line is +0.15 per cent and −0.25 per cent or a total of 0.4 per cent. The ±0.2 per cent develops around a mean output value which occurs at some input voltage below nominal. Load regulation at low line is only +0.05 per cent from half to no load but is −0.25 per cent from half to full load. Total load regulation of 0.3 per cent is equally divided around the load point that represents about 85 per cent of full load.

Line-and-load total regulation is the difference between the highest output voltage which usually occurs at high-line no-load, and the lowest output which usually occurs at low-line full-load. In this case the total variation is 0.5 per cent or ±0.25 per cent about the mean value.

Note that adding the line regulation of ±0.2 per cent to the load regulation of ±0.15 per cent gives a total of ±0.35 per cent, although the line and load regulation combined is only ±0.25 per cent. The reason for this is that the low output-voltage value at low line and full load contributes a major part of both line regulation and load regulation.

It is sometimes desirable to specify regulation to remain within a certain range regardless of what causes the change. The first step is to combine line, frequency, and load regulation. The next step, often used in computer design, is to state that the instantaneous voltage must stay within a certain plus-or-minus percentage. This adds peak ripple and maximum excursion (or dynamic regulation) to line and load. Adding stability changes also gives total

Table 2—Ranges of Power-Supply Characteristics for Various Types of Regulators*

Type of Supply	Output Range			Regulation		Ripple	Response Time
	Voltage (v)	Current (amp)	Power (kw)	Line (per cent)	Load (per cent)	(per cent)	(millisec)
Unregulated	5 to 2500	0 to 1000	0 to 30	None	± 3 to 15	0.1 to 5	
Line Regulated							
Electronic regulator	5 to 2500	0 to 1000	0 to 30	± 0.1 to 1	± 3 to 15	0.1 to 5	100 to 500
Resonant regulator	25 to 600	0 to 50	0 to 10	±0.25 to 2	± 2 to 5	0.1 to 5	100 to 250
Line-and-Load Regulated							
Resonant regulator	25 to 600	0 to 50	0 to 3	±0.25 to 1	±0.25 to 1	0.1 to 1	200 to 500
Magnetic-amplifier Regulator	5 to 300	2 to 1000	0.5 to 30	± 0.1 to 0.5	± 0.1 to 0.5	0.1 to 1	100 to 250
Vacuum-tube regulator	150 to 2500	0 to 5	0 to 3	±0.01 to 0.25	±0.01 to 0.25	2 to 10†	0.05 to 0.1
Transistor regulator	0 to 300	0 to 15	0 to 0.5	±0.02 to 0.25	±0.02 to 0.25	1 to 5†	0.05 to 0.1
Thyratron-tube regulator	50 to 600	5 to 100	0.5 to 60	± 0.1 to 0.25	± 0.1 to 0.25	0.1 to 1	50 to 250

*These figures are by no means limiting values, and in some cases much better results can be obtained at higher cost.
†These values are in millivolts.

regulation. It is also possible to lump together the line, frequency, load, and stability factors where transient changes are unimportant.

Power-Supply Regulators

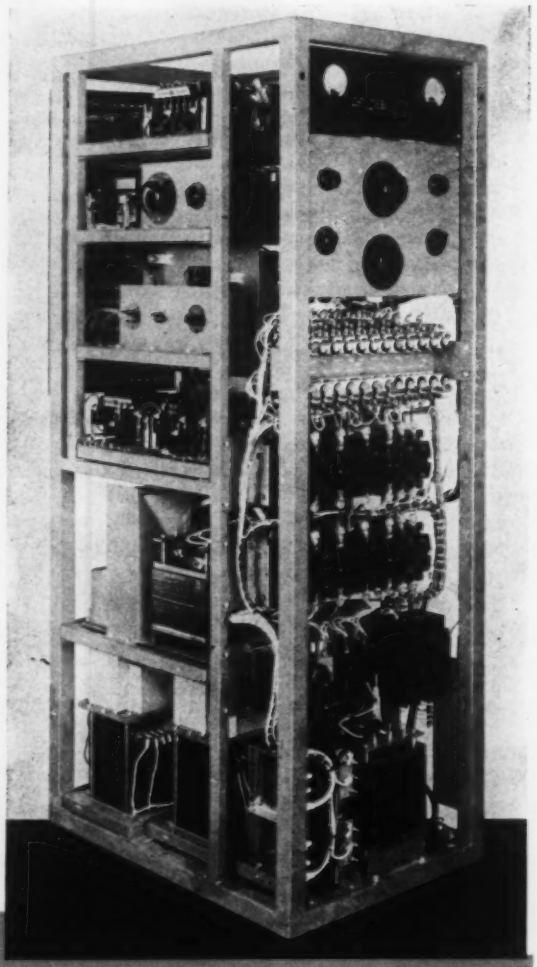
This section discusses various methods of regulating the output voltage of electronic power supplies. In Table 2 are listed typical ranges of values of both regulation and other principal characteristics available, using each method of regulation. These figures are by no means limiting values and in some cases much better results can be obtained at additional cost. These higher-cost units are, however, mostly precision laboratory supplies for design, research, and development work.

Unregulated Supplies: These units are smaller, lighter, and cheaper than regulated supplies. However, the output is subject to change with input line and load changes. Adding a variable autotransformer allows the user to adjust the output to make up for these changes, but the response time is that of the human operator unless motor-driven systems are used. It is also a nuisance to keep adjusting for line and load changes. For supplies incorporated into systems or used on production lines, adjustment to overcome regulation becomes difficult.

There is no limit to the voltage and current ratings available with unregulated supplies except that at low voltages the load regulation becomes poor. Large three-phase input supplies give better regulation than small single-phase units.

Line-Regulated Supplies: To eliminate effects of line variation, ac regulators can be placed in front of unregulated dc supplies. This is a particularly useful method when a large number of supplies are being regulated using one regulator, or when regulation of ac voltage is also required.

Although this method is obviously better than nothing, it has pitfalls. The dc output voltage is basically proportional to the average or peak value of ac voltage, depending on whether choke or capacity-input filters are being used, while ac regulators usually regulate rms voltage. In addition, cur-



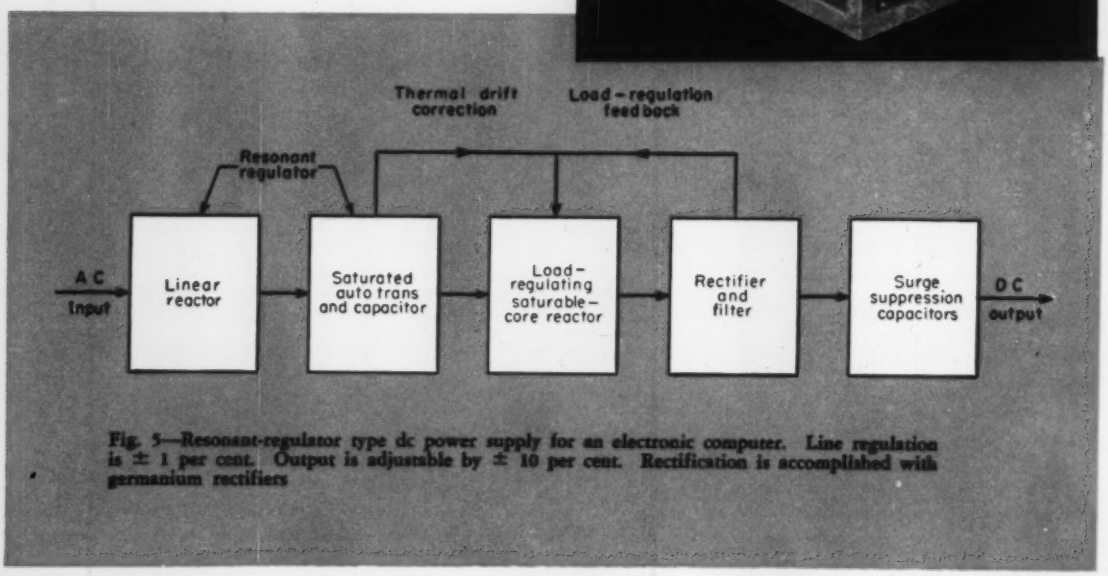


Fig. 5—Resonant-regulator type dc power supply for an electronic computer. Line regulation is ± 1 per cent. Output is adjustable by ± 10 per cent. Rectification is accomplished with germanium rectifiers

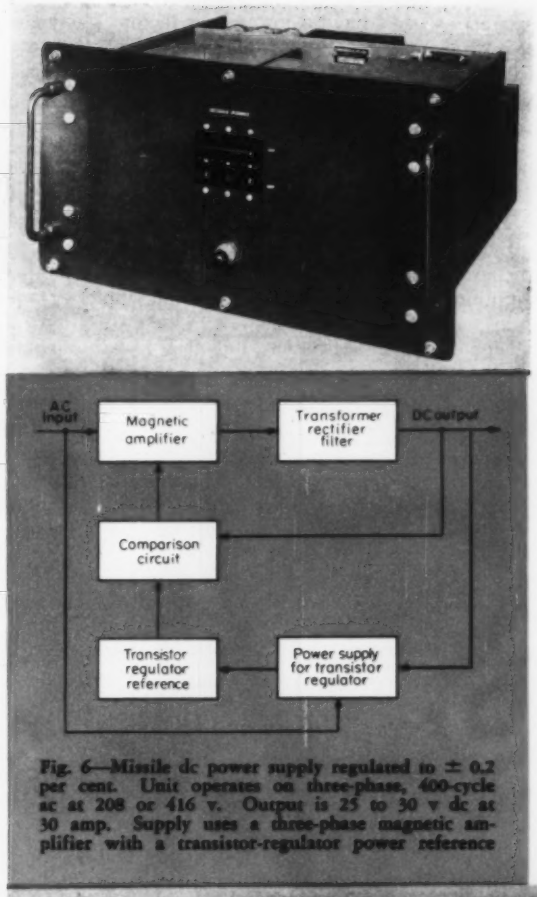


Fig. 6—Missile dc power supply regulated to ± 0.2 per cent. Unit operates on three-phase, 400-cycle ac at 208 or 416 v. Output is 25 to 30 v dc at 30 amp. Supply uses a three-phase magnetic amplifier with a transistor-regulator power reference

rents drawn by power supply are nonsinusoidal, approaching square waves for choke input and consisting of narrow pulses for capacity input. These currents distort the output wave shape of the regulator, affecting the average-to-rms and peak-to-rms ratio of the wave.

The preceding effects cause the dc output voltage regulation to be worse than the ac regulation; in fact, the dc output regulation may be several per cent using a ±0.1 per cent electronic regulator. In addition, the line regulation of the ac voltage out of the regulator becomes worse. These effects are much more pronounced with capacity-input filters, especially with half-wave rectifiers.

If, instead of an electronic type regulator, a resonant regulator, Fig. 5, variously known as magnetic voltage regulator or constant-voltage transformer, is used, the degeneration of regulation of the dc output against the ac input is not as pronounced. This type of regulator, however, only regulates to ±0.5 per cent over input range of 95-130 v. Improvement in dc regulation to these figures can be made by designing the regulator specifically for the dc load. This also allows the rectifier input transformer of the unregulated supply to be eliminated, since necessary ac voltage to give proper dc output can be obtained by providing isolated secondary windings as part of the resonant regulator. Several dc outputs can be supplied from one regulator in this manner.

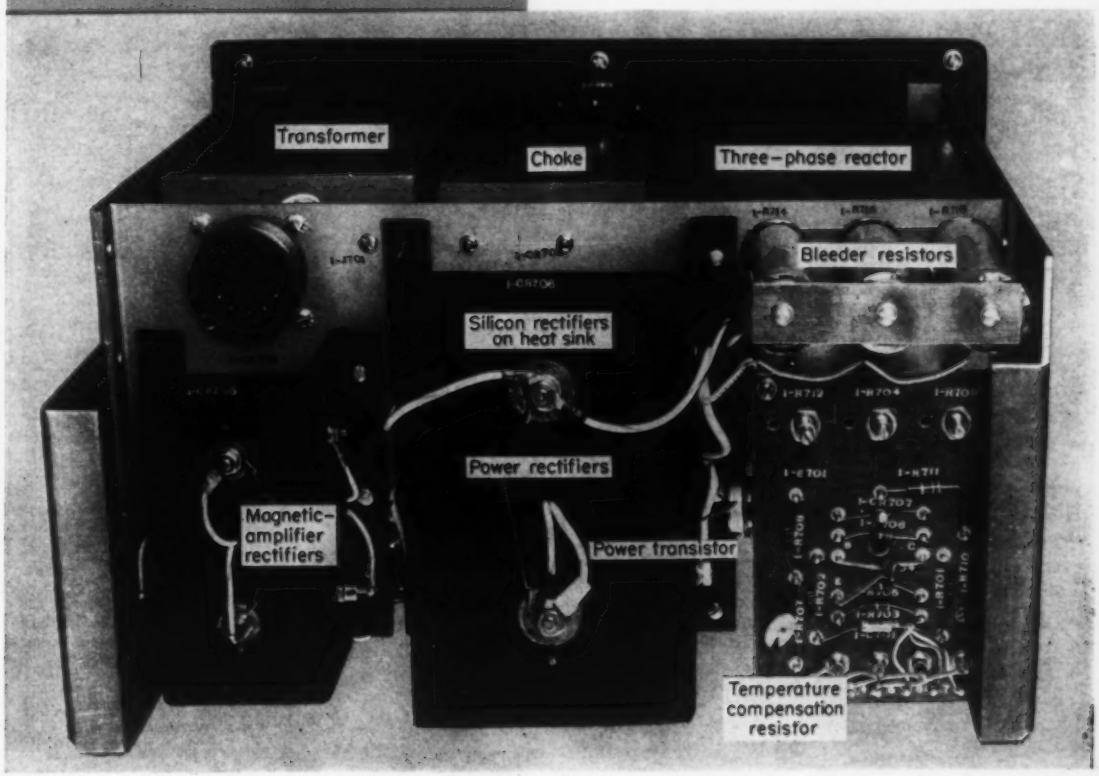


Fig. 5 shows a computer power supply in which is included several multioutput regulators. The resonant regulator has the further advantage that it suppresses line-voltage transients.

Load-Regulated Supplies: If line regulation is not used, load regulation can be achieved by use of a variable reactance controlled by load current. A simple method of achieving this is to use a choke input filter circuit in which the choke saturates below full load. This reduces inductance of the choke enough so that the output voltage tends to rise toward the capacity-input value, reducing regulation. A more accurate way is to add an auxiliary saturable-core reactor ahead of the rectifier whose impedance can be controlled by feeding back the load current through the control winding of reactor.

Line-and-Load Regulation: If the load-regulating circuit described previously is added to the resonant regulator type of unit, the resulting power supply has reasonable regulation for line and load. Typical units are of this type are shown in Fig. 1 and 6.

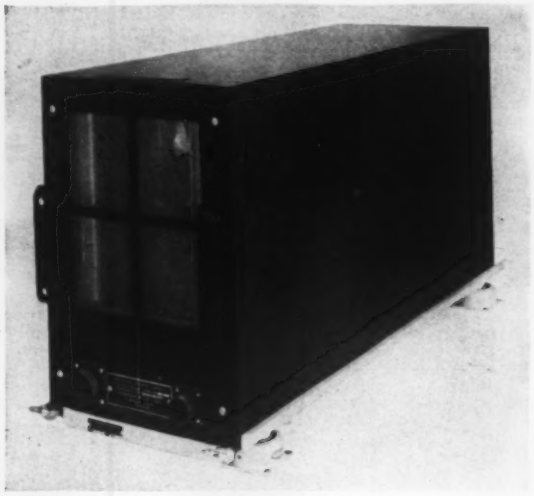
In low-power circuits, voltage-regulator tubes and Zener diodes, which are normally used as references, can be used as regulators.

Magnetic-Amplifier Regulators: Magnetic amplifiers either in more recent self-saturating circuits or in older simple saturable-core reactor circuits offer a prime means of obtaining good regulation against line and load up to large power levels. They offered, until the recent advent of transistors, the most efficient way of regulation at lower voltages.

Being essentially a reactive device, they are slow in response and have a low power factor. They can operate over wide output-voltage adjustment ranges with no auxiliary devices and are only slightly sensitive to frequency.

Vacuum-Tube Regulators: Known as B supplies, these units regulate by controlling the voltage drop across a series passing tube. The output voltage is compared against the voltage of a voltage reference tube and the difference is amplified and applied to the grid of the passing tubes. Output ripple is also amplified causing most of the input ripple to appear across the passing tube.

This type of regulation has fast response com-



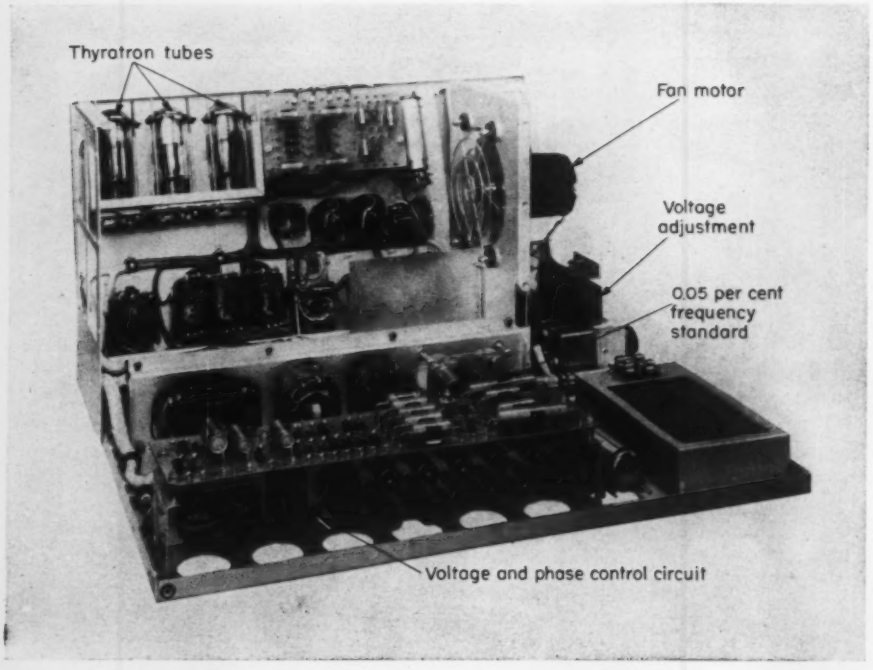


Fig. 7 — Airborne, two-phase frequency changer with a 115-v, 400-cycle output. Sides of unit unlatch and lay flat when opened, permitting easy access for maintenance purposes

pared to that of magnetic amplifiers, and low ripple is obtained by electronic means. Since regulation is achieved by resistive rather than reactive means, power factor is improved but efficiency is poorer. Disadvantages are losses and warm-up delay caused by tube filaments as well as less reliability because of the large number of tubes required.

Transistor Regulators: Transistors are now replacing vacuum tubes as series passing elements. All the basic characteristics of tube type units are available at better efficiency because of the lower voltage drops across the transistors. The Zener diode replaces the voltage-regulator tube to give a completely tubeless and fast-response regulator. Losses and delay of tube filaments are eliminated in transistorized circuits. At present the transistor regulator is replacing tube regulators at lower voltage levels and magnetic-amplifier regulators at lower power levels. As transistors with higher current and higher voltage ratings become available, the field where this type of regulator is superior will grow.

Thyratron-Tube Regulators: For high-voltage, high-current supplies the number of tubes and the power lost in them become prohibitive in passing-tube circuits. The thyratron tube will control large currents with small drops. Regulation and control are accomplished in one device. Output is regulated by controlling the point in cycle where the tube is fired. Radio-frequency noise is generated by this circuit, however, and filtering is not always satisfactory.

Combination Regulators: Sometimes several types of regulators are combined. For example, resonant regulators or magnetic amplifiers can be used as preregulators to reduce the voltage swing and power loss of tubes or transistors.

▶ Electronic Frequency Changers

The electronic frequency changer, Fig. 2 and 7, provides the designer with a compact combined source of signal and power output in a single package. This type of power supply is usually operated on 50 or 60-cycle ac power. The designer must specify whether output frequency is adjustable or fixed, and if adjustable, over what range. Specifications should be given on volt-ampere output, voltage regulation, frequency regulation, and response time when ordering a frequency changer.

The inverter frequency changer falls into the circuit category of a wave-forming network as distinguished from two other closely related circuits—oscillator amplifiers and pulse-forming networks. The distinguishing feature separating it from these other circuits is the fact that it uses thyratrons as switches. The high gain of the thyratron circuit permits a high power output to be realized in only one stage, as contrasted with the many stages required in an audio amplifier to obtain the identical power output. For instance, frequency changers that are now being developed can generate 5000 v-amp in one stage.

Output Ratings: Excellent frequency regulation is one of the outstanding features of frequency changers. That is, at fixed frequencies, extremely accurate frequency regulation can be realized through the use of tuning-fork oscillators. For instance a recent 60-cps application required 0.001 per cent accuracy at 60 cps for a unit supplying 1000 v-amp at 115 v. The same unit also supplies 45-65 cps by use of a toggle switch to insert a Wein-bridge type oscillator. Frequency dial calibration over the range can be approximately 0.5 per cent. At present, standard frequency changers have frequency ranges covering 45-65 cps, 360-440 cps, and 320-1000 cps with harmonic distortion of 5 per cent nominal.

Comparison Data: Basically there are two kinds of frequency changers—the inverter type and the amplifier type. Electronic inverter-type changers are capable of operating power-factor loads of 0.5 to unity and are available in power ratings from 250 to 1000 v-amp. The actual frequency control, therefore, can be obtained at the front panel similar to that of an audio oscillator. The output voltage range obtainable is usually in the order of 100-130 volts and is controlled similarly.

Much wider frequency and voltage ranges are available if an amplifier-type frequency changer is used. However, this type does not operate well into inductive loads and requires derating. For instance, a standard unit rated at 100 v-amp is derated to 75 v-amp with a unity to 0.5 change in power factor. It offers a wide frequency and voltage range from 45 cps to 2 kc and 0-130 v, respectively, with a maximum harmonic distortion of 1 per cent.

The inverter type is capable of a considerably greater ratio of watts per unit volume. For instance a 360-440 cps, 1000 v-amp unit requires 4.13 cubic feet whereas a 100 v-amp amplifier type requires 2.12 cubic feet of volume. The figure of merit for these two units is about 5 to 1.

In summary, the inverter type electronic frequency changer is highly desirable from the viewpoint of power-to-volume ratio and watts-per-dollar ratio in the larger sizes. Also, it has better voltage regulation and stability. The inverter types have higher overload capacity and are capable of higher output power at the center of the frequency range; whereas, amplifier types generate a fairly constant capacity versus frequency. In addition to this, the inverter type is excellent for inductive loads including operation of motors. The amplifier type has low distortion, wide voltage and frequency ranges and is generally considered a superior unit for general laboratory applications. The actual application of the frequency changer will be the final determining factor.

Specifying and applying

AC and DC ELECTRIC

Types of generator prime movers
Electrical power-output options
Coupling and mounting requirements
Prime-mover and generator controls
Industrial and mobile applications

Electric power of practically any voltage or frequency can be obtained with standard or special-design generators. If ac, voltage can be single or polyphase, low frequency or high. Both ac and dc types can be supplied with either constant or adjustable output characteristics. Many other design options are available as standard equipment.

MOTOR-GENERATOR sets and rotary converters serve as a means of changing the frequency, voltage, or phase of the central-station power for special applications, Fig. 1. Such equipment is also used to change alternating current to direct current, convert dc to ac, or stabilize frequency or voltage.

Turbine or engine-driven generators, Fig. 2, used as independent ac and dc power sources find wide

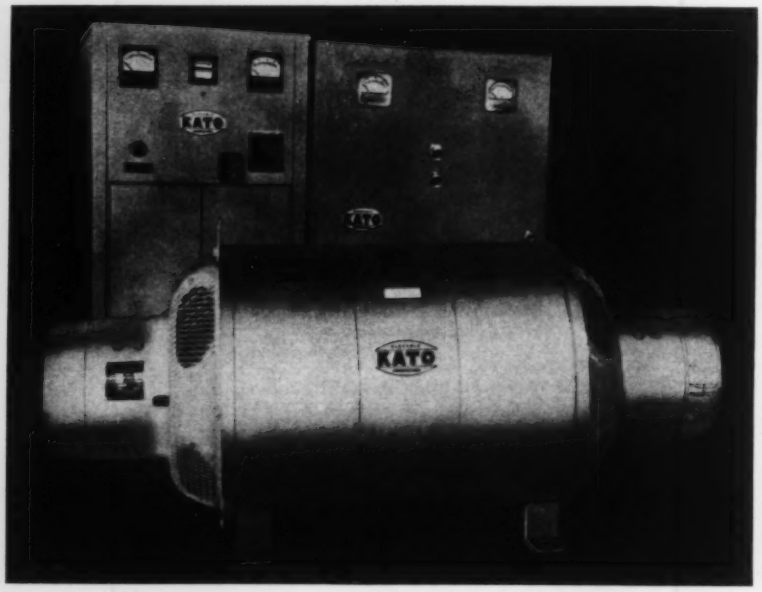


Fig. 1 — Motor-generator set which changes 60-cycle, three-phase current to 400-cycle ac. The motor is synchronous and is mounted on a shaft common to the generator. At left is generator control unit with voltmeter, frequency meter, ammeter, selector switch, and voltage adjust rheostat for the automatic voltage regulator. Motor-starter cubicle at right contains input ammeter, motor-field ammeter, and the synchronous motor starter

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GENERATORS

Fig. 2 — Engine-generator power plant for use on jet-plane test equipment. The 1000-watt, 400-cps generator is driven by an air-cooled gasoline engine

application in design. Standard-frequency 50 and 60-cycle engine-generator systems within the range of 5 to 400 kw output are applied in machines and equipment which will not be used near electric power lines.

Successful application of generators in the design of independent power supplies and power-changing equipment depends on how well power, control, and prime-mover requirements are specified. A check list of factors to consider in specifying a generator and the associated control and drive equipment is given in Table 1. Typical electrical performance characteristics for 60 and 400-cycle ac generators are listed in Table 2.

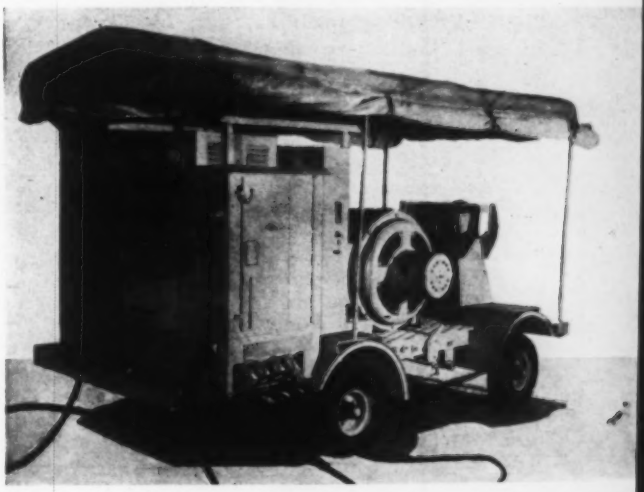
Motor-Driven Generators

Aeronautical developments during the past decade have greatly extended the use of 400-cycle and other high-frequency ac generators. The use of high-frequency electronic equipment in missiles and other aircraft has created a tremendous need for high-frequency electric power equipment for testing components in missiles, radar, and related equipment, Fig. 3. Often, the test current is from a motor-generator set. These units are built in three basic designs. The motor and generator may be in a common frame on a common shaft, Fig. 3 and 4, in separate frames and direct-connected with a coupling, Fig. 5, or in separate frames with belt-drive arrangement.

Speed of the drive motor in relation to the desired output frequency usually determines the type of drive arrangement. If the motor and generator are to be direct-connected, the output frequency of the generator must be a multiple of the motor frequency.

How the type of drive arrangement depends on

Fig. 3—Portable motor-generator power supply used by the Missile Development Div., North American Aviation Inc., to furnish preflight power for guided missiles and missile checkout trailers. Input power is 60-cycle ac and output is 400-cycle ac. Direct-connected rotating exciters for both motor and generator are mounted on driveshaft extensions



these factors is illustrated by the following example. An ac generator always has two or more field poles and the total number of poles is always divisible by 2 since there must always be at least one plus and one minus pole. Ac generator output frequency $F = PS/120$ where P = total number of poles, and S = rotational speed in rpm.

Therefore, if a 40-pole alternator is operated at exactly 1200 rpm, the output frequency, F, will be exactly 400 cycles per second since $40\ (1200)/120 = 400$. If the 60-cycle, 6-pole, 1200-rpm motor is of the synchronous type, the frequency will be exactly 400 cps, providing the input line is constant 60 cps. The motor and generator in this case could be coupled directly together.

If the motor driving speed is not a multiple of the desired generator output frequency, the units must be belt-driven. For example, if the previously discussed generator must have an output frequency of 440 cps, the generator would have to operate at a speed of 1320 rpm. If the driving motor is fed from 60-cycle lines, the generator would have to be belt-driven to change the speed ratio from 1200 to 1320 rpm to produce the desired frequency of 440 cycles.

When induction-type motors are used to drive a generator, allowance must be made for motor slip. Speed of the motor will vary slightly from a relatively small percentage when no load is applied to the generator to a greater value as load is increased. For this reason, the amount of motor slip in relation to load must be considered when specify-

Table 1—Checklist for Specifying Motor and Engine-Driven Generators

1. Prime Mover
- a. Engine data
- b. Motor data
- c. Steam-turbine data
- d. Other

2. Mechanical Adaptations to Prime Mover
- a. Mounting feet and base provisions
  - If direct-connected
  - If belt-driven
- b. Drive coupling
- c. Bell housing adapter
- d. Outlet box location
- e. Painting requirements
- f. Provisions for mounting control equipment

3. Generator Output Data
- a. Power rating, kw
- b. Power rating, kva
- c. Power factor
- d. Voltage requirements
- e. Speed
- f. Frequency
- g. Phase
- h. Type of excitation desired

4. Electrical Load Characteristics
- a. Duty factor, operating durations, and percentage of full load
- b. Type of wiring service
- c. Type of load
  - Inductive load—induction motors, etc.
  - Capacitive load—synchronous motors, etc.
- d. Maximum load to be applied
- e. Summary of the end use or application

5. Electrical Performance Factors
- a. Voltage regulation
- b. Response time
- c. Maximum voltage dip
- d. Maximum voltage overshoot
- e. Transient reactance
- f. Phase balance
- g. Waveform
- h. Efficiency

6. Generator Control Equipment
- a. Voltmeter
- b. Ammeter
- c. Frequency meter
- d. Running-time meter
- e. Wattmeter
- f. Watt-hour meter
- g. Power-factor meter
- h. Volt-ampere reactance meter
- i. Recording meters
- j. Indicating lights
- k. Instrument selector switches
- l. Necessary resistors, shunts, current transformers, and potential meter transformers for the meters
- m. Overvoltage and undervoltage protection
- n. Circuit breakers for main and distribution lines
- o. Trip to enable the breakers to be opened electrically from a remote station
- p. Main-line fuses
- q. Control-circuit fuses
- r. Radio filtering within the line
- s. Synchronizing features to synchronize two or more generators
- t. Static field exciter
- u. Manual field adjust
- v. Automatic voltage regulator
- w. Combination automatic voltage regulator and static exciter
- x. Radio shielding (standard equipment with most generators)

7. Motor Controls for Motor-Generator Sets
- a. Manual or automatic motor starting controls
  - Synchronous motors
  - Dc motors
  - Induction
  - Other
- b. Centrifugal governor which acts as a speed detector to keep circuits closed until a predetermined frequency or voltage is attained
- c. Remote area receptacles and substation controls for both motor and generator
- d. Speed governor to maintain constant speed and thus constant frequency and voltage—rotating, finger or Thyrite types
- e. Manual, pushbutton, or pushbutton remote controls for varying the drive speed of motor-generator sets if of the adjustable-frequency type

8. Engine Controls for Engine-Driven Generators
- a. Controls for automatic starting from a remote area
- b. Electric starting
  - Cranking winding in generator
  - Separate generator shaft-mounted starter
  - Separate engine-mounted starter
- c. Trailer or dolly mounting base
- d. Steel base or skid mounting
- e. Engine-battery trickle charger
- f. Battery overcharge protection
- g. Protective metal hood or housing
- h. Automatic transfer switch from line to standby generator
- i. Load-demand starting and stopping provisions
- j. Provisions for starting from remote locations
- k. Time-delay starting and stopping provisions
- l. Provisions to start plant for brief exercising periods
- m. Overspeed protection
- n. Engine speed governor controls
- o. Remote area receptacles and substation controls for both motor and generator
- p. Audible and visual danger signal provisions
  - High water temperature
  - Low oil pressure
  - Overcrank

9. Installation Environment
- a. Climatic conditions
- b. Dust conditions
- c. Space requirements
- d. Cooling air provisions
- e. Engine exhaust provisions

Table 2—Electrical Performance Characteristics* for 60 and 400-Cycle Ac Generators

Characteristic	400-Cycle Generators		60-Cycle Generators	
	Small	Large Up to 300 kw	Small	Large Up to 500 kw
Voltage regulation				
Inherent (per cent)	20 to 30	25 to 40	15 to 25	25 to 35
With regulator (per cent)	±2 (½ special)	±2 (½ special)	±2 (½ special)	±2 (½ special)
Response time (sec)	0.05 to 0.5	0.2 to 1	0.2 to 1	0.5 to 5
Maximum voltage dip (per cent)	10 to 25	20 to 30	10 to 25	20 to 30
Maximum voltage overshoot (per cent)	10 to 25	20 to 30	10 to 25	20 to 30
Transient reactance (per cent)	15 to 30	15 to 30	10 to 20	15 to 30
Phase balance with balanced loads (per cent)	1	1	1	1
Waveform				
Harmonic content (per cent)	1 to 3 of total	1 to 3 of total	3 to 6	3 to 6
Deviation factor (per cent)	3 to 5	3 to 5	4 to 8	4 to 8
Crest factor	1.35 to 1.46	1.35 to 1.46	1.31 to 1.51	1.31 to 1.51
Form factor	1.08 to 1.15	1.08 to 1.15	1.05 to 1.18	1.05 to 1.18
T.I.F. (telephone influence factor)			150 to 300	150 to 300
Efficiency (per cent)	65 to 85	85 to 93	70 to 90	90 to 96

*These are average values and can be improved for special applications.

ing a generator which will be induction-motor driven.

Large motor-generator sets are usually built to operate at slower speeds than smaller units. Common rotational speeds of 60-cycle, synchronous motors are 600 rpm (12 poles); 900 rpm (8 poles); 1200 rpm (6 poles); 1800 rpm (4 poles); and 3600 rpm (2 poles). These same combinations apply to 60-cycle ac generators.

Some cities and most ships are supplied with direct-current power. When alternating current is required, a dc-to-ac converter or motor-generator set is often employed. Motor-generators are also used to change ac to dc when a small amount of direct current is needed for testing or other purposes.

After power has been transmitted for long distances and the voltage stepped up or down through transformers, there may be voltage fluctuations. Since voltage can only be regulated at the source, a motor-generator set with the input characteristics the same as the output might be used to stabilize voltage. The output voltage of the motor-generator set can be easily regulated.

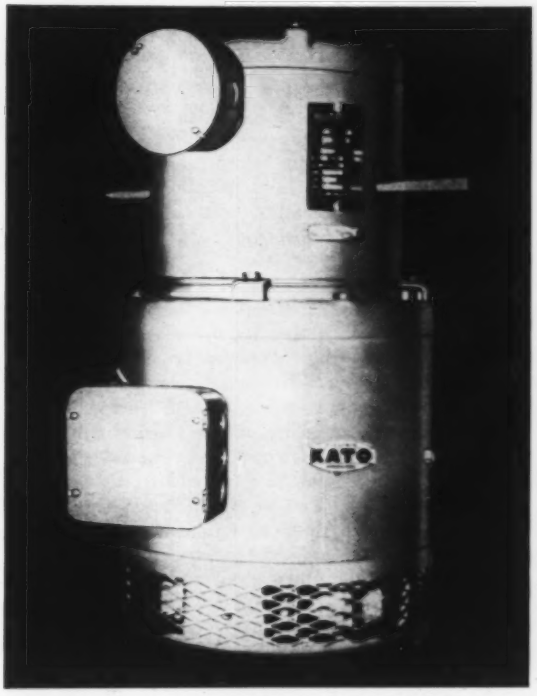


Fig. 4—Vertical motor-generator set designed to operate on 60-cycle ac. Output frequency of generator is 360 cps. The higher frequency, when superimposed on standard 60-cycle lines, is used to interrupt frequency-selective circuits, permitting remote on-off operation of industrial or commercial power equipment

Engine-Driven Generators

Since a great variety of engines are used in the fabrication of equipment using engine-driven generators, specifications must include the make and model of the engine to which the generator is to be adapted as well as other pertinent engine information. In Fig. 2 is a gasoline-powered generator unit and in Fig. 6 is a diesel-powered engine-generator set used in a railroad application. Usually, the adapter which mounts the generator to the engine and in many instances the drive coupling as well are supplied by the electric generator manufacturer.

To insure accurate alignment, the designer should specify the distance between the face of the engine bell housing and the face of the engine flywheel in order to compute corresponding difference between the coupling face and the adapter face. The adapter is first bolted to the generator, usually at the factory, and the adapter face which is designed to fit the engine bell housing must be machined and drilled to specifications at the factory. The coupling and fan assembly, which is bolted to the driving flange must also be drilled to fit the bolt mounting-hole drillings of the engine flywheel. The flange is usually sweated onto the generator shaft.

If the designer specifying a generator supplies his own coupling, he should include in the specifications the dimensions and provisions for mounting the coupling to the generator shaft as well as information concerning the coupling in relation to the generator fan. Engine flywheel and bell-housing dimensions should spell out the amount and size of bolt holes, and the diameters of the bolt circles.

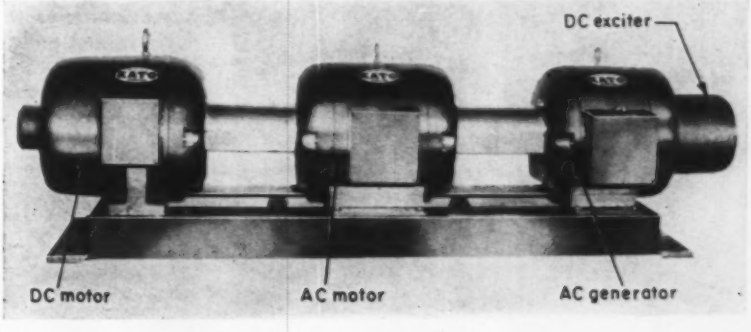


Fig. 5—Electric three-phase generator direct-coupled to a dc drive motor, ac drive motor, and rotating dc exciter. Generator is normally operated by the ac motor. In the event of an ac power failure, a load-demand transfer switch causes dc motor to be energized by storage batteries to drive the generator. Speed of dc motor is governor-controlled

A dimensional drawing of the engine bell housing should be supplied if possible.

The SAE bell housing adapter size (1, 2, 3, etc.) should also be specified if known. If special base-mounting provisions are required, specify whether the outlet box should be mounted on the left or right of generator and if the direction of rotation should be other than counterclockwise, facing the generator from the commutator end. The shaft height, which is the distance from the shaft center to the mounting surface, should be indicated.

The control equipment and electrical performance features required and the type of control panel desired should also be specified. Since overspecifying the controls may result in increased cost, it is usually better to list control characteristics desired rather than specific controls.

Any pertinent information concerning the climatic and other operating conditions should be described, since special insulation or other component modifications may have to be incorporated in the fabrication of the generator.

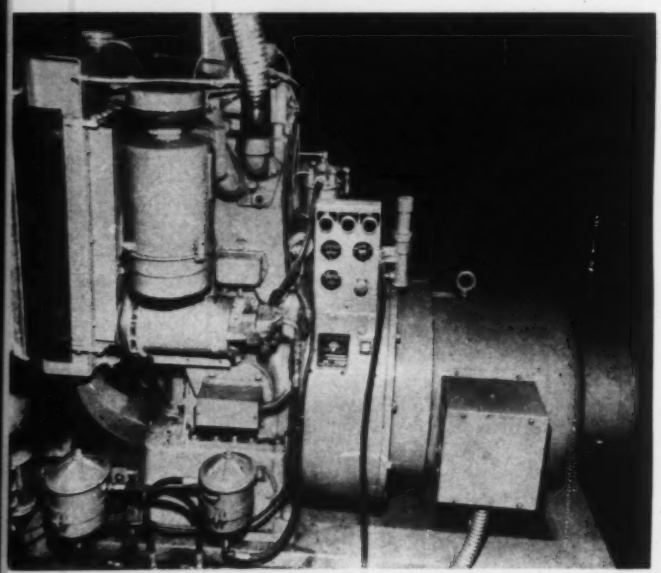
Any special generator enclosure features, such as a dripproof or splashproof design, should also be indicated.

Electrical Load Data: Since the end use of the equipment determines the necessary characteristics of any generator, the nature of the load which will be applied should be accurately determined.

The total power consumption of all motors, lights, and other equipment should be added and allowance made for planned load increases in order to specify a generator of the proper rating for any particular system. Most motors require three to five times as much current when starting as running. When computing the motor load which will be applied, it usually is only necessary to include the starting current of the largest motor and the running current of all other motors.

The various voltage requirements throughout the load should also be analyzed carefully. Although there is danger of overspecifying, specs must indicate the voltages which are required to operate the various load components.

Fig. 6—Diesel-operated engine-generator power plant for new Milwaukee Road cabooses. A one-cylinder Nordberg diesel engine drives the generator which provides 5 kw of 120-v, single-phase ac power for operating communications equipment, electric stove and refrigerator, and light fixtures. Entire set is mounted on special shock-resistant mounting rails to help engine withstand the shocks encountered in railroad service



Control Equipment

A revolving-field alternator with 12 lead wires brought out from the generator stator permits connecting the lead wires for several different voltages. This provides optional hookup of either series or parallel and wye or delta. For example, a 60-cycle, three-phase, 12-wire generator with different hookups could supply the following voltages: Parallel delta, 120 volts; parallel wye, 120/208 volts; series delta, 240 volts; and series wye, 240/416 volts. With a rheostat or voltage regulator, these voltages can be changed within a range of approximately ±5 per cent. Other 12-wire generators have the same hookup combinations and with various types of windings, many different voltages are possible.

Control equipment and indicating meters may be required in many cases and may be only a convenience in others. The equipment required may vary from a simple dc exciter-field rheostat to an elaborate automatic load-demand transfer system.

Two meters which are desirable, however, are a voltmeter and an ammeter. The voltmeter determines if the voltage output is correct for the equipment in use. The ammeter reading determines if the amperage corresponds with the amperes per terminal marking on the generator nameplate. The combined readings of the two meters will determine the kva consumption.

The necessary indicating meters and control equipment can be built into a control cubicle, or if the control panels or cubicles are relatively simple, they can be mounted directly on the generator. If considerable control equipment is required, it is usually incorporated in a large free-standing cubicle, Fig. 1, or wall-mounted panel. The controls for a housed or mobile unit are built into a section of the housing.

A partial list of controls for both generator and prime mover incorporated into a complete power system are listed in items 6, 7, and 8 in Table 1.

ACKNOWLEDGMENT

The author wishes to thank Ellis Olson and Detlev Mohrmann, electrical engineers at Kato Engineering Co., for their assistance in developing this article.

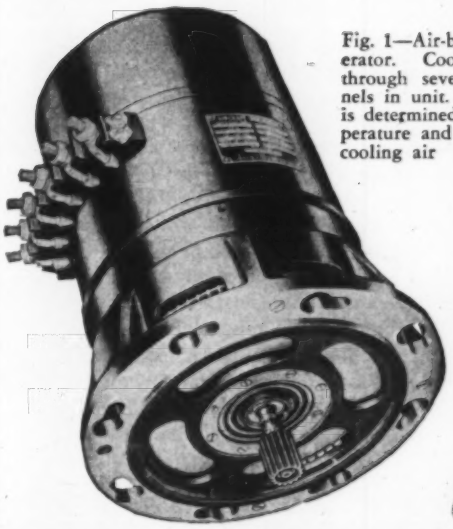
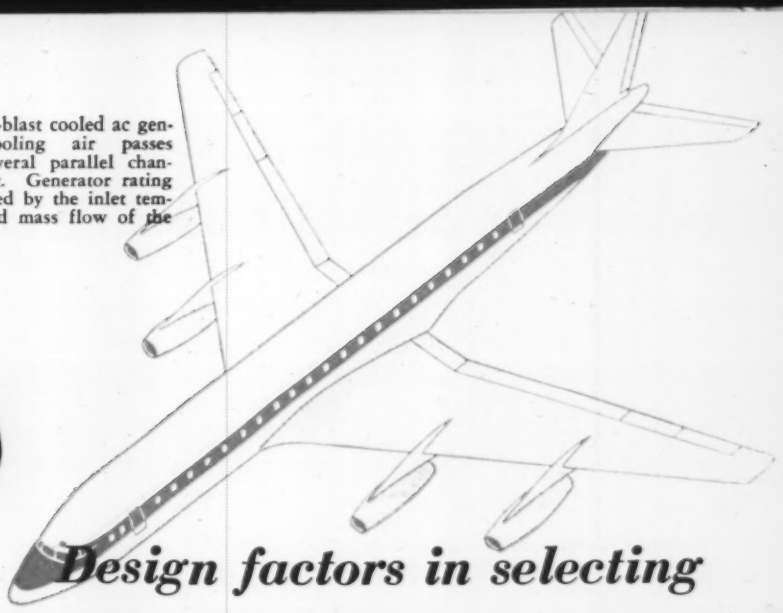
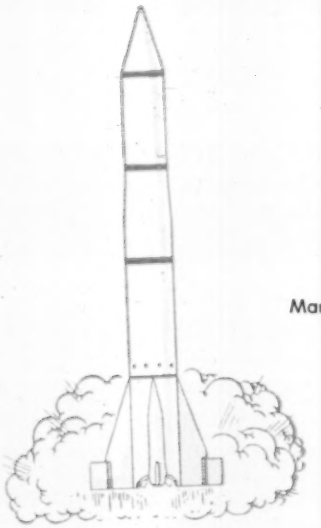


Fig. 1—Air-blast cooled ac generator. Cooling air passes through several parallel channels in unit. Generator rating is determined by the inlet temperature and mass flow of the cooling air



Design factors in selecting

Lightweight Electric Generators



Generator cooling methods
Electric power vs. weight data
Generator-excitation methods
Voltage and frequency regulation
Airborne applications in design

By CHARLES H. GRACE and **JAMES N. HIBBARD**
Manager, Controls and Systems Engineering — Manager, AC Generator Engineering
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In design applications where size and weight are critical, such as aircraft and missiles, special lightweight electric generators and control equipment meet the demands for high power-weight ratios. Among the many factors influencing selection of a system, the method of cooling the generator in high-speed flight usually stands at the top of the list. Generator electrical type, voltage-regulation accuracy, and other factors help establish final system design.

STRIKING design differences appear when airborne electric power generating systems and industrial systems are compared. For example, a 45-kw airborne generator with integral exciter weighs 110 lb, is 15 in. long and 10 in. in diameter; an industrial generator of the same rating weighs 875 lb, is 35 in. long and 25 in. in diameter. The difference in size and weight reflects the design objectives—aircraft systems are designed for high rotating speeds consistent with maximum reliability for minimum weight, while industrial systems are designed for minimum maintenance cost over a long life. Aluminum and magnesium are used in aircraft generators wherever possible instead of ferrous metals, and operating temperatures of bearings and insulation are considerably higher. Also, airborne systems generally employ positive forced cooling. Because of these differences in design objectives and functions, aircraft-system life is measured in hours—about 1000 to 2000—instead of years. Of course, a generator for a missile may have a life requirement of only a few minutes.

Selection of an airborne electric generator and the associated regulating system for a particular application requires a thorough design analysis of many interrelated factors—each application requiring an individual study. This article describes the design and application factors which must be con-

sidered and presents data which will assist in choosing a generator and regulator, with special emphasis on weight and reliability.

Methods of Cooling

Since generator cooling plays an important role in selection, several practical methods of cooling will be discussed first.

Air-Blast Cooling: The most commonly employed type of cooling is an air blast picked up by a scoop on the airplane. This technique is effective because generators can readily be designed to channel the cooling air flow into direct contact with the heat-producing parts. Fig. 1 shows an air-blast cooled ac generator for airborne applications. Cooling air enters the blast cap, passes through several parallel channels in the generator and exits through ports at the rear. Generator rating is determined by the inlet temperature and mass flow of its cooling air. A class C machine, for example, is designed for rated operation with 120 C maximum inlet air temperature and mass flow corresponding to a pressure drop through the generator of 11 in. of manometer water. The temperature of inlet air available for cooling depends upon the altitude and speed of the aircraft. Fig. 2*a*, which shows a typical family of inlet air temperature curves as a function of altitude and flight speed, demonstrates that the inlet air temperature is 120 F cooler at 40,000 ft altitude than at sea level. This difference increases the cooling effectiveness of each pound of air, but the advantage is offset by lower air densities at the higher altitudes and the higher speeds at which high-altitude aircraft normally fly.

Aircraft-generator manufacturers prepare altitude rating charts for their air-cooled designs, which take into account the temperature and mass-flow conditions just described. These charts show the maximum continuous load-carrying capacity of the generator at various altitudes and inlet air conditions.

Oil Cooling: At supersonic flight speeds and continuous flight at high altitudes, air-blast cooling is less effective. In fact, the temperature of the air may approach or even exceed the allowable temperatures of the insulation and bearings. For these flight conditions, a circulating coolant such as oil that passes through an external heat exchanger may be employed. In Fig. 3 is an oil-cooled 20 kva ac generator and a schematic of the path of the cooling liquid.

The most commonly used coolant is the air-

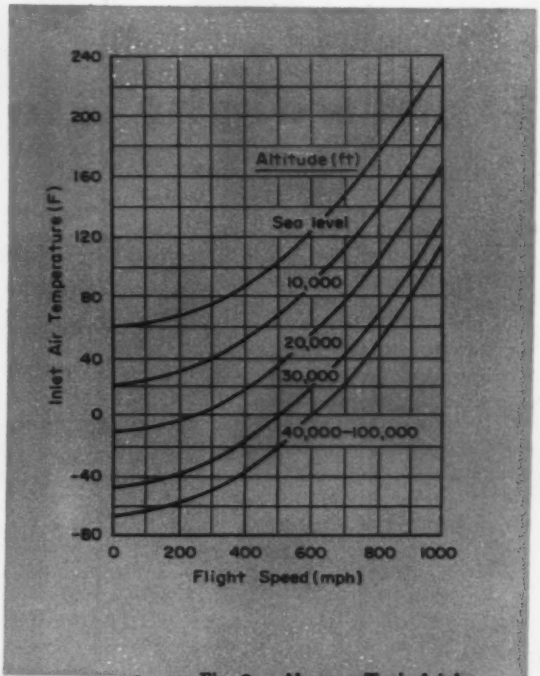


Fig. 2 — Above — Typical inlet air temperature curves for aircraft as a function of altitude and flight speed. Inlet air temperature equals ambient plus temperature rise caused by flight speed

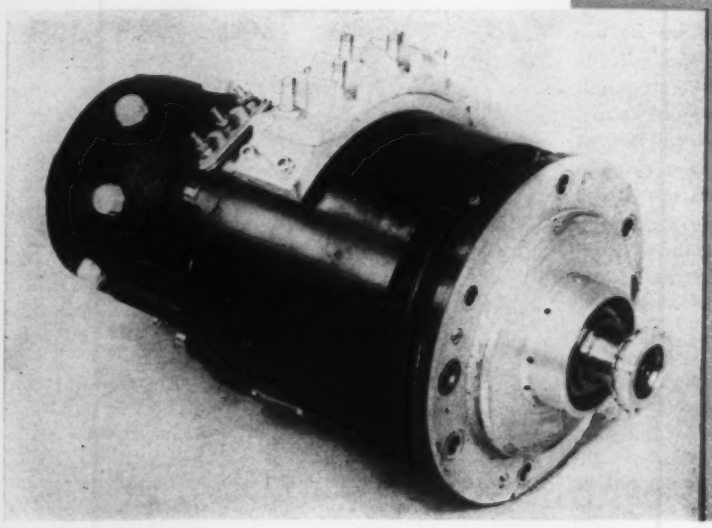


Fig. 3—Left—Oil-cooled, three-phase ac generator is rated at 20 kva and has an integral dc exciter. Carbon-face seals are employed between rotating and stationary members for transmitting oil

craft engine oil, which is circulated to the generator mounting pad and into the generator where it passes through the stator and rotor and back out to the heat exchanger. A recirculating system such as this is adaptable to varying conditions of flight because the heat sink can be easily transferred as the environment changes. For example, during supersonic flight the inlet air temperature for a liquid-to-air heat exchanger may be too high for adequate cooling but, at the same time, fuel consumption of the engine may be great enough to permit use of the fuel as a heat sink. For lower flight speeds, when the fuel is not a good heat sink, the liquid-to-air heat exchanger may be re-employed.

Primary advantage of the oil-cooled generator is that it is more environment-free than air-cooled machines. One of its principal disadvantages is that oil must be confined to ducts and pass through rotating seals from the stator to the rotor; hence a sealing problem is introduced. Satisfactory operation of commutators and brushes is also more difficult to achieve with oil cooling because oil vapors caused by leaks have adverse effects upon commutation. Oil vapors on slip rings, however, appear to be advantageous insofar as brush operation is concerned. This situation favors the elimination of commutators on oil-cooled generators.

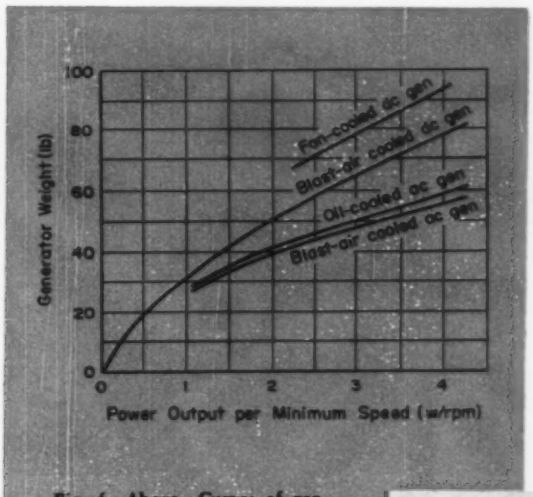


Fig. 4—Above—Curves of generator weight versus electric power output in watts per rpm

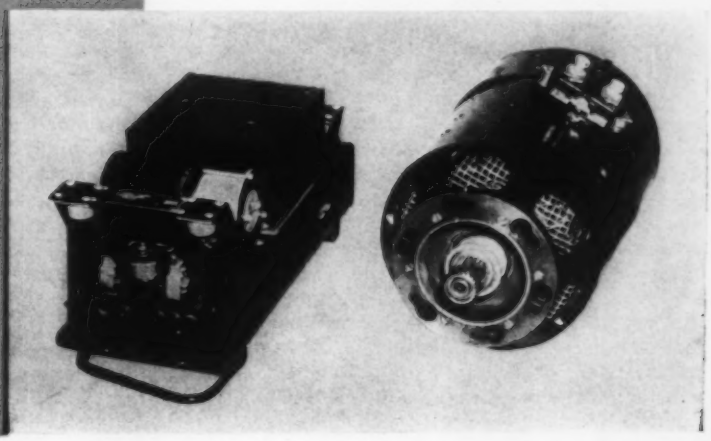


Fig. 5—Right—Air-blast cooled, 28-v dc generator which is popular in light aircraft. Regulator is a carbon-pile type

Evaporative Cooling: The coolant is injected directly into the generator when evaporative cooling is used. Here the evaporant is heated to the boiling point, evaporated, and exhausted as a vapor. Since the heat of vaporization is used as the heat sink, generator temperature remains practically constant during the heat absorption. This condition insures a maximum mean temperature difference between the surface to be cooled and the coolant. Generators cooled in this manner are therefore even less environment-dependent than oil-cooled generators. Also, their construction is simpler, with coolant entry tubes, temperature-sensing, and coolant-control devices being the only auxiliary cooling equipment needed. Vaporization cooling has been restricted, however, by the lack of completely satisfactory evaporants. Ideally, the evaporant should have a high heat of vaporization, moderate boiling temperature at atmospheric pressure, and low freezing temperature. Although it does not meet all these requirements, water has been successfully used. Sufficient evaporant must be carried to cool the generator for the duration of each flight.

Thermal-Lag Generators: So-called thermal-lag generators are not designed for temperature stabilization with a continuous rated load. All the heat produced must be stored in the mass of the generator parts. Thermal-lag generators are often used where the duration of the flight is short, as with missiles. Generators of this type will fail after a certain time if the load is not disconnected.

Self-Air-Cooled Generators: This type of machine uses a built-in fan to circulate the cooling air. Inverters and ground-power generators are frequently designed with built-in fan cooling, and often a

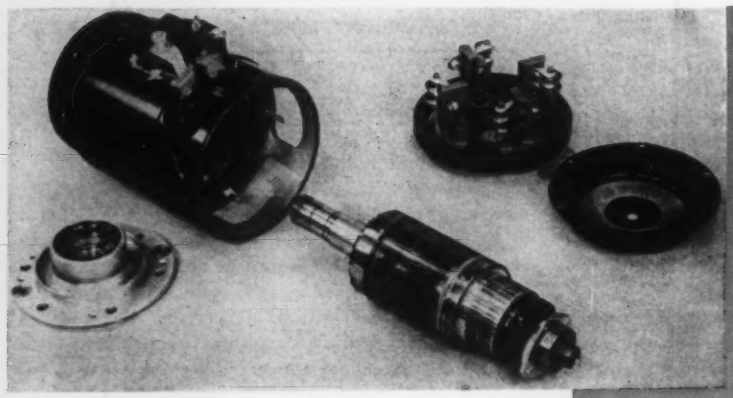
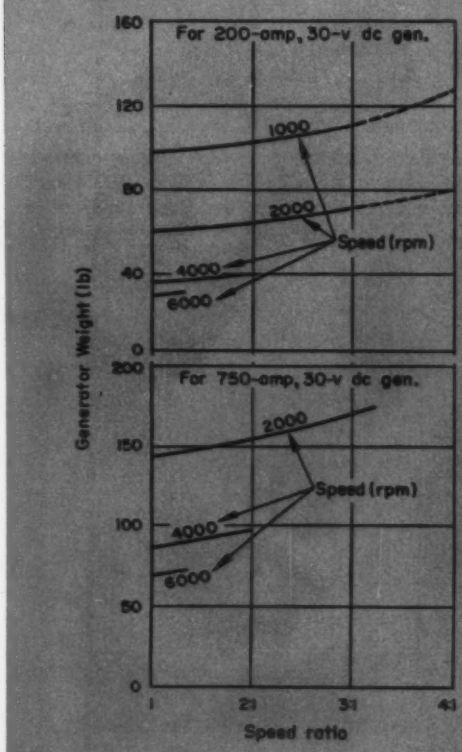


Fig. 6 — Left — Oil-cooled generator which operates at 8000 rpm and is rated at 100 amp, 30-v dc

Fig. 7 — Below — Charts showing factors that affect weight of 30-v dc generators. Weight is lower when driving speed is higher and speed ratios are lower. Output current and minimum speed are primary weight-controlling parameters



fan must also be added to airborne blast-cooled generators. This is necessary when airplane ground operation requirements are such that the generator will overheat if some air circulation is not provided. Therefore, commercial airplanes frequently have fans on their blast-cooled generators.

Comparison of Cooling Methods: Weights of generators cooled by various means are compared in Fig. 4. Selection of the best cooling system depends upon altitude, flight speed, ambient temperature, and the duration of flight. For moderate altitudes and speeds the blast-cooled generator is best because of its simplicity and reliability. Its rating chart can be used as a guide to determine the point at which liquid cooling is needed. Beyond that limit, oil-cooled units are best for flights of long duration, although liquid-evaporating types may also be adequate. Thermal-lag generators are suitable only for very short flights.

▶ DC Electric Generating Systems

After the cooling factors have been fully evaluated, then the designer must decide whether he needs an ac or dc system. Components in dc systems are presented here first.

DC Generators and Regulators: Generators rated at 28 v dc are popular in light aircraft, especially personal and executive types. An air-cooled dc generator for this type of service and its regulator and controls are shown in Fig. 5. In Fig. 6 is a disassembled dc generator. The weight of dc generators decreases at higher shaft speeds and increases slightly with increases in the ratio of engine speeds over which the generator must operate, Fig. 7.

Usually dc generators are shunt-wound and often employ carbon-pile regulators, Fig. 8. The carbon pile is a stack of wafers under spring pressure. Pressure on the stack can be varied by an electromagnet, changing the electrical resistance of the carbon stack; hence, the current in a circuit connected in series with the carbon stack can be controlled by varying current in the magnet coil. The carbon pile is connected in series with the field of the generator. In aircraft where more than one dc generator is employed and the generators are to be connected in parallel, load sharing is controlled by a second coil on the carbon pile magnet, whose current is determined by the difference between each generator's current and the average current of all of the generators, as measured by an equalizer bus. The critical relationship between pressure and stack resistance makes carbon-pile regulators relatively troublesome.

DC-to-AC Inverters: Most airplanes require both ac and dc power for their various loads and regardless of whether the primary generated power is ac or dc both types must usually be provided. If the

primary generated power is dc, inverters are used for obtaining the necessary ac power, Fig. 9. These are usually rotating units comprised of a dc motor coupled to an ac generator, with the speed and voltage regulated by means of their field windings. Static or motionless inverters, that is, transistor oscillators, are also being developed, particularly for light ac loads.

Rectified AC Systems: Primary dc power may be obtained by generating ac and passing it through a transformer-rectifier unit. This type of system weighs more than dc generators except at very high power ratings.

AC Electric Generating Systems

Three-phase generators are preferred over single-phase units because of the better power-output waveform and reduced system copper losses for a given rating.

Ac systems can be designed for constant frequency or variable frequency. The design of the loads is simplified if a constant frequency system is used; however, for certain loads such as de-icing and cabin heating the frequency does not matter.

Frequency Regulation: Electric generators are usually driven by the aircraft engines; consequently, variations of engine speed cause changes of output frequency in the ac system. To obtain a constant-frequency system, therefore, a mechanical variable-ratio transmission must be interposed between the aircraft engine and the generator so that the generator shaft speed is constant regardless of engine speed. These constant-speed drives are of various types. The most popular is a special hydraulic pump connected to a hydraulic motor with provision for varying the ratio of input to output speed. These units are capable of transforming a 3-to-1 variation in input speed to an output shaft speed which is constant to within ±2 per cent for all loads within the generator rating. The drive speeds are controlled by a speed-sensing device and a servomechanical loop.

AC Generators with Rotary DC Exciters: The diversity of applications has resulted in development of a multitude of different ac systems. The most common type of system is described here, then others will be reviewed. The most common system comprises a synchronous alternator, a dc exciter generator mounted on the same shaft, and a magnetic amplifier regulator.

In Fig. 10 is an ac generator with a rotary dc exciter mounted integrally on the same shaft. The output voltage of the alternator is regulated by controlling field current of the dc exciter. Salient-pole synchronous generators are the most popular. Good regulation, stability, and reasonably fast response to changing conditions are provided by regulator and exciter-generator combinations. Variations in terminal voltage are sensed by the regulator, which controls the field current of the exciter which, in turn, controls the alternator field current. Constant terminal voltage under widely varying load conditions can be obtained.

Output of the dc exciter generator is transmitted to the main generator field through a commutator and slip ring assembly. The rotor assembly of Fig. 10 shows the field winding of the alternator, the armature of the dc exciter, the exciter commutator, and the alternator field slip rings. Since the dc exciter is usually capable of building up

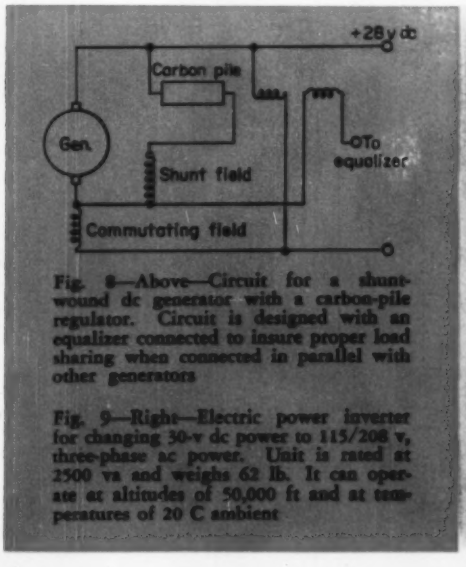


Fig. 8—Above—Circuit for a shunt-wound dc generator with a carbon-pile regulator. Circuit is designed with an equalizer connected to insure proper load sharing when connected in parallel with other generators

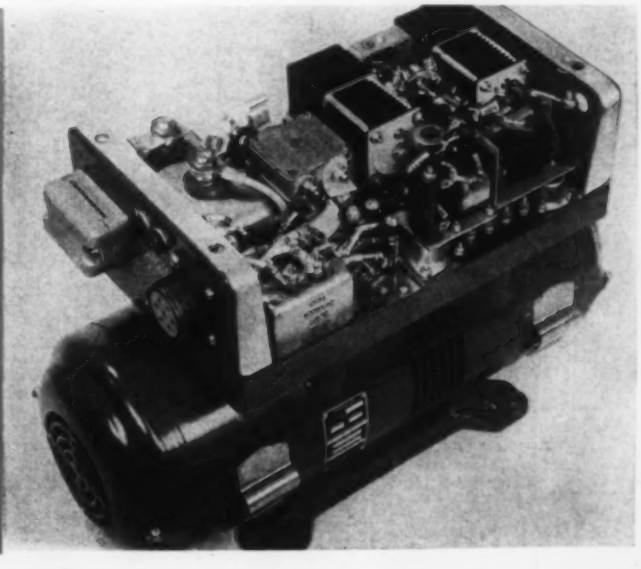


Fig. 9—Right—Electric power inverter for changing 30-v dc power to 115/208 v, three-phase ac power. Unit is rated at 2500 va and weighs 62 lb. It can operate at altitudes of 50,000 ft and at temperatures of 20 C ambient

from its own residual voltage, the conventional generator is self-starting. Under short-circuit conditions when the line voltage is unable to provide power for the regulator, the dc generator can be utilized to provide large short-circuit excitation currents for burning out faults and fuses by having its exciter field shunt-connected through a relay. A block diagram of a conventional system is depicted in Fig. 11*a*. The major disadvantage of the dc exciter is that it requires brushes, which are troublesome in severe application. Both commutator and slip-ring brushes are required.

Regulators for Integral Exciters: The basic elements of a conventional voltage regulator, Fig. 12, are a sensing circuit, a voltage reference circuit, and a comparison arrangement for producing the error signal in a magnetic amplifier whose output current drives the field winding of the exciter generator. In addition, antihunting circuits and temperature compensation are usually required.

In generating systems operated in parallel, a second input signal to the regulator is also required for proper division of reactive load among the generators. When the regulator is connected to control the field current of an exciter generator as described previously, the regulator can be smaller than would be necessary if it supplied the field winding of the ac generator directly, but the stability problem is aggravated because of additional time delay in the exciter field.

Performance criteria for regulator-generator systems are:

1. Constancy of amplitude of the generated voltage with changing load and environmental conditions.
2. Minimization of harmonics introduced on the output waveform by the regulator.
3. Minimization of hunting, which appears as amplitude modulation on an ac system.
4. Maximum speed of response of the system when electrical load changes occur.
5. Capability for supplying fault-clearing short circuit currents.

When generators are operating in parallel, the voltage regulator of each generator has control over the division of current among the generators of the reactive load only and does not control the division of real load. The latter is determined by the settings of the speed governors on the constant-speed drives. Reactive load must be divided properly among the generators, however, because a generator that carries too great a share of the reactive load may heat excessively. Also an underexcited generator has less synchronizing torque, so it is more susceptible to

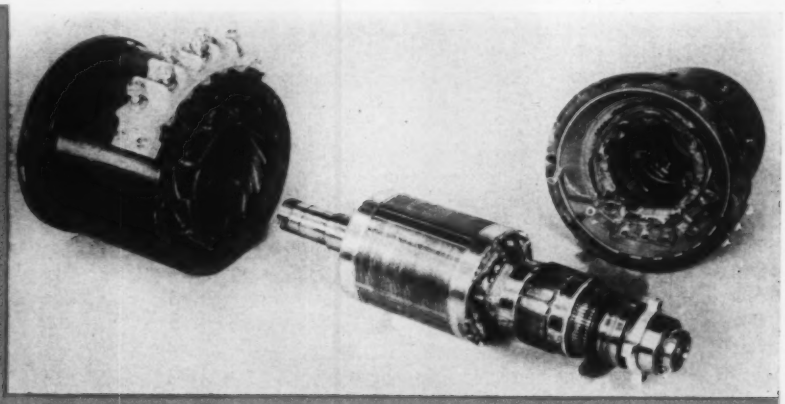


Fig. 10 — Oil-cooled ac generator with rotary dc exciter. Alternator is driven at 12,000 rpm and develops power in the form of 115/208 v, three-phase alternating current. Housing is cast from lightweight magnesium. Leads from slip rings to the alternator field windings pass through shaft

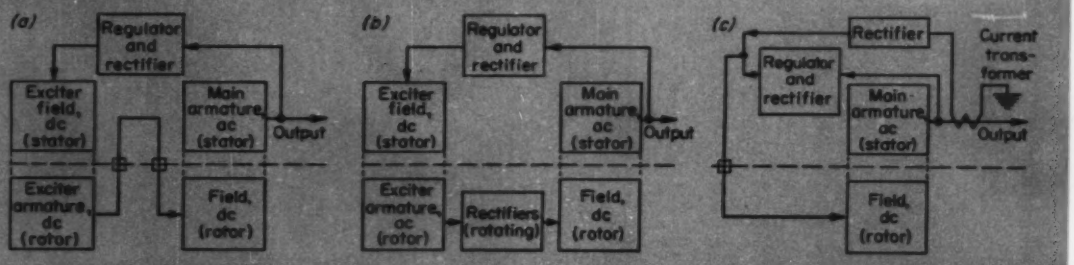


Fig. 11—Three methods of exciting the dc rotating field of an ac generator. In *a* is a conventional excitation system using a dc generator. In *b* a brushless ac generator with a rectified output is used. In *c* field excitation current is supplied directly from alternator terminals and current transformers on feeder cables. Elimination of rotary-type exciter greatly improves speed of response since only one field time constant is involved

pull-out. For these reasons a voltage regulator for a parallel generator system must have an auxiliary input which controls the field excitation according to the amount of imbalance in reactive current carried by the various generators.

Rotary AC Exciter Systems: In Fig. 11*b* is shown a rotary ac exciter system. The dc exciter is replaced by an ac exciter, and dc power from the main field of the alternator is obtained by rectification of the ac exciter output. The rectifiers are mounted on the rotor so that no brushes for either the exciter or the alternator field are required. This is particularly significant at high speeds and high altitudes where oil cooling is used. A disadvantage of a brushless excitation system is that the rectifiers, which are mounted on the rotor, must be kept cool.

Static Exciter Systems: Fig. 11*c* shows an excitation system which requires brushes riding on slip rings, but it eliminates the necessity for brushes on commutators. There is no rotating exciter. Power for field excitation is drawn from the output terminals of the generator and passes through a regulator and rectifier, then through slip rings to the rotor of the alternator. A second source of field power in parallel with the first source is required because without it the generator would not be able to provide field current for itself in the case of a serious short circuit in the load. Since a short-circuit fault reduces the voltage at the generator terminals, the output of the static exciter is reduced. That further reduces the output voltage if the operating range of the regulating scheme is exceeded, and the system collapses. This is undesirable because the generator must provide short-circuit currents long enough to operate overcurrent protective devices. After the faulty load is removed by fuses, the generator may supply the remaining loads. If the generator were turned off immediately, all loads would lose power.

The static exciter eliminates this disadvantage by using current transformers on the feeder cables. In case of a fault, the field draws its power from the current transformers. Static exciters have the further advantage that if a fault such as a two-line-to-neutral short circuit occurs between the generator terminals and the current transformers, the generator turns itself off automatically. The system collapses because both voltage and current transformer input to the regulator become very low. This is desirable because the feeders, unlike the loads, cannot be protected conveniently with fuses so that a partial load can still be carried in case of a fault.

Output voltage of a generator departs from its regulated value temporarily when a heavy load is suddenly added or removed. The magnitude and duration of the line-voltage transient resulting from load changes should be minimized to protect sensitive loads. Static exciters excel in this respect.

Carbon-Pile Regulation: A carbon-pile regulator may be used to control the field current of a rotating dc exciter, an ac exciter, or an alternator,

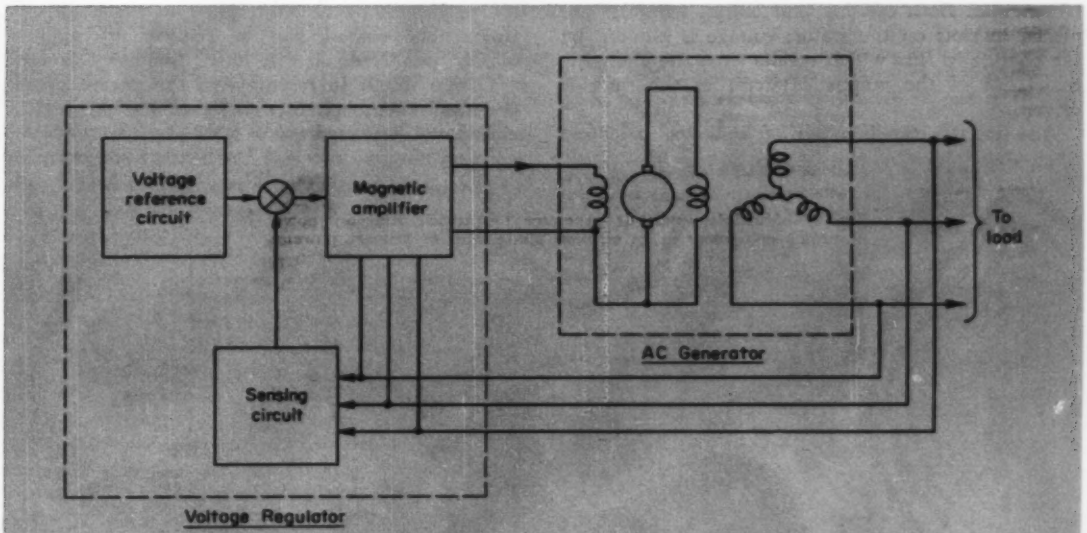


Fig. 12—Elements of a magnetic amplifier regulator. Error signal between sensing circuit output and voltage reference controls amplifier. Output of magnetic amplifier is the field current for rotary dc exciter

but magnetic amplifier types are preferred.

Permanent-Magnet Generators: Where reliability is very important and where the weight penalty incurred is tolerable, a permanent-magnet generator may be used as the prime source of electrical power. They are usually used in system ratings below 10 kva. They may be regulated by saturating the stator back-iron or by using permanent-magnet field poles with an electromagnetic boost of controlled amount. Permanent-magnet units are normally built for 400 cps at speeds of 6000, 8000, or 12,000 rpm, although designs have been made for frequencies as high as 10,400 cps at 48,000 rpm.

Other AC Power Sources: Whether rotating or static exciters are used, airborne synchronous generators are generally constructed with salient poles for operation at 6000, 8000, or 12,000 rpm. Cylindrical-rotor synchronous generators have also been built, but presently most generators are designed for a constant frequency of 400 cps, and the cylindrical rotor type does not have a weight advantage until a speed of about 24,000 rpm is reached.

Power for special loads such as computer systems is sometimes supplied by high-speed, high-frequency inductor generators which are driven directly. These are brushless machines which may or may not be excited by permanent magnets. In appearance, inductor generators are similar to squirrel-cage induction motors with the exception that there is no rotor winding and the rotor slots are rectangular. Both exciting and output windings are placed in slots on the stator; voltage is induced by the change in flux which results from the changing reluctance of the magnetic circuit as the rotor is driven.

Also in the classification of inductor machines is the flux-switch generator. It has a different number of poles on the rotor and stator, arranged so the flux is alternately reversed in the stator windings. Either permanent magnets or wound-field windings are employed.

Another brushless machine suited to high-speed direct connection to a turbine is the induction generator. It is the same as a squirrel-cage induction motor except it is driven slightly above its synchronous speed. The induction machine is one of the most rugged and dependable types. In missile work, the generator can be used as a motor for certain ground check-out operations when it is not desirable to drive the prime mover. Its disadvantage is that it must obtain excitation from an external power source; where used with loads having a lagging power factor, the amount of capacitive correction needed for the generator becomes quite large, disqualifying the machine on a weight and space basis. Hence this generator is usually used only for high power factor loads and fixed loads as on missiles.

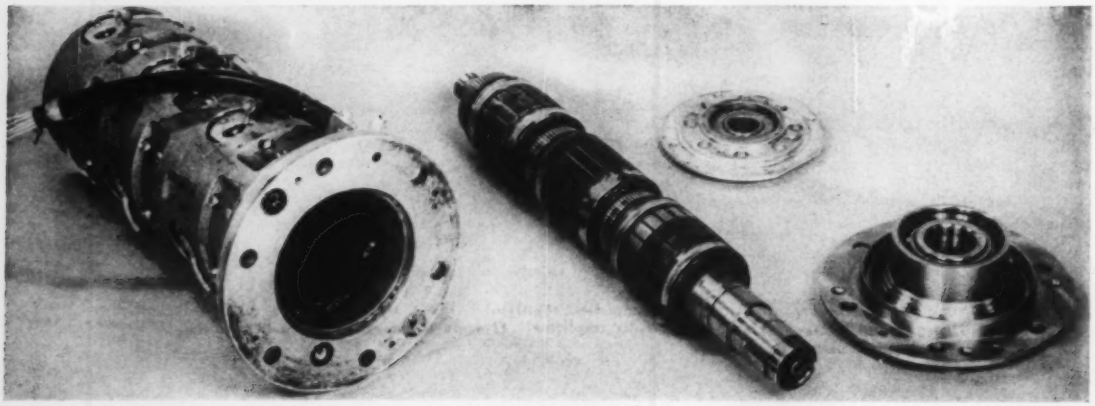
Secondary DC Loads: When the primary generated power is ac, the dc secondary loads must be supplied by a motor-generator or a transformer-rectifier set. Fig. 13 shows three dc generators mounted on a single shaft which may be driven by an ac motor. These generators are used to supply high-voltage electronic loads.

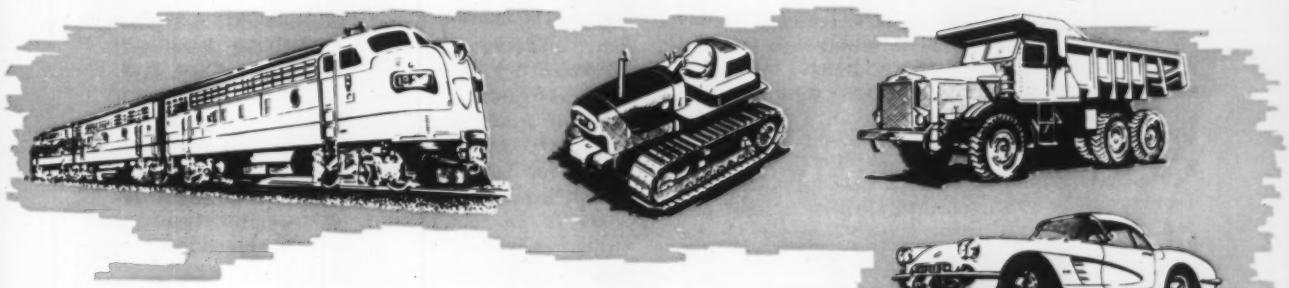
Design Summary

The question often arises about the advisability of using some higher frequency instead of 400-cycle ac systems, and there has been increasing discussion in recent years of changing to a frequency in the neighborhood of 3000 cps. The weight of electromagnetic devices can be reduced by approximately two-thirds if this latter frequency is used.

Design trends in recent years are toward greater precision in the characteristics of the power generated and increased use of static devices.

Fig. 13—Multiple-output dc generator to provide auxiliary power to electronic equipment in an airplane along with ac primary power

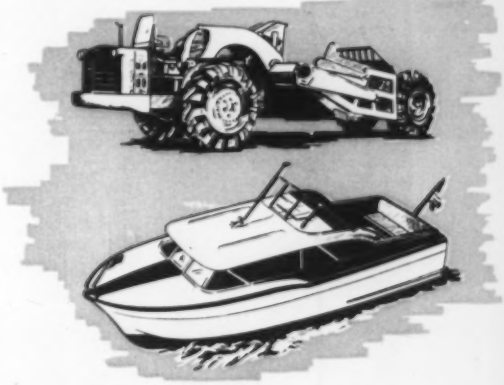




Factors in designing

Generator-Battery Systems

Electrical compatibility considerations
Mechanical design factors
Influence of changing environments
Design installation suggestions
Vehicle application data



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Electric power systems designed with both generators and storage batteries are standard in most land and water vehicles. Integration of these radically different power sources into the same electrical system presents problems in matching performance characteristics to vehicle electrical load demands. The design problems are often further complicated by extreme temperature changes and severe shock and vibration conditions in service.

EVER since the introduction of an electrical system in vehicles, particularly passenger cars, more and more applications have been found for using this source of power. Naturally, greater usage creates greater demands upon the two components which provide the electrical power —the generator and the battery. Other design factors which enter the picture are mechanical considerations, environmental conditions, type of service, mounting, ambient temperatures, accessibility, speed range, and life expectancy. Each of these topics are important in generator-battery system design and are discussed here.

Electrical Loads: Generator-battery systems are used on many types of vehicles—passenger cars, trucks, tanks, tractors, off-the-highway equipment, airplanes, boats, power mowers, and even caddie carts. Some of the better known components powered by this seemingly unlimited source of energy are:

Air-conditioning blowers	Heater blowers
Antenna motors	Horns
Buzzer systems	Ignition systems
Cigarette lighters	Light-dimming systems
Compressors	Lighting systems
Convertible-top motors	Radios
Cranking motors	Seat controls
Defroster blowers	Transmission controls
Directional signals	Transmitters
Door locks	Warning devices
Gages	Windshield wipers

A few years ago, many of these loads were beyond anyone's imagination; consequently, it is quite conceivable that several new demands for electrical power will arise in the next few years. This load increase applies to all types of vehicles. For example, lights have been applied on farm tractors for night-time plowing for a number of years, and now radios have been added. Fig. 1 illustrates the rapidly increasing electrical load demands on passenger cars. In the 1925 to 1930

period, an average of 100 watts was used to supply all electrical equipment of a continuous-operation nature, while in 1958 approximately 560 watts are required. If the rate of increase continues, and all indications are in that direction, a demand for 800 to 1000 watts, or even more, can be expected within a few years.

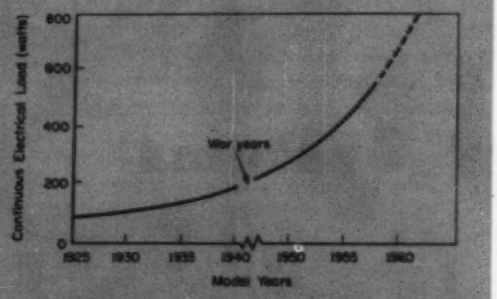


Fig. 1—Electrical load demands of past, present, and future American passenger cars

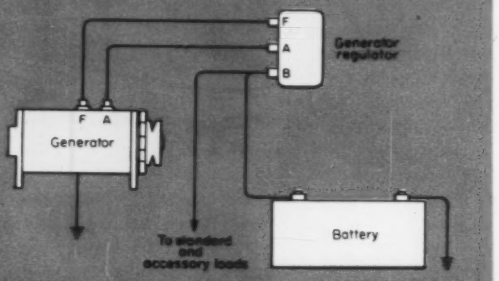
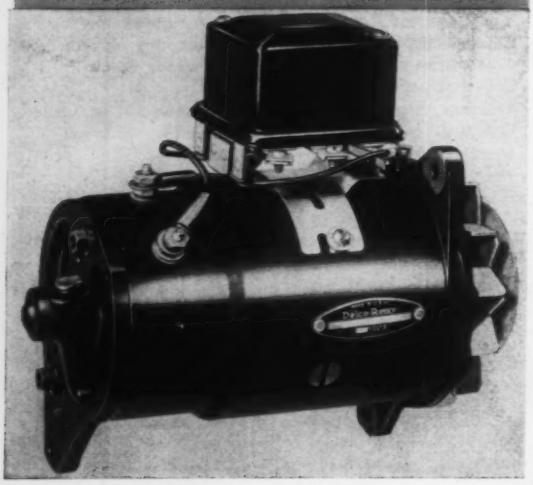


Fig. 2—Above—Conventional circuit arrangement of battery, generator, and generator regulator for an automotive vehicle

Fig. 3—Ventilated dc generator designed for application on farm tractors. Voltage regulator is mounted directly on the generator



Generator-Battery System Components: A typical generator-battery system, Fig. 2, includes three basic components: 1. A dc generator. 2. A battery. 3. A generator-regulator. The generator, when driven at a sufficient speed, must be capable of supplying all connected continuous loads and still have a small reserve for battery charging as well as for intermittent loads. The battery must have sufficient capacity to provide adequate cold-weather cranking without specific gravity of the electrolyte decreasing to a marginal level. The generator-regulator performs three functions in the modern generator-battery system: 1. The current-limiting device protects the generator from overheating. 2. The voltage-limiting device controls the charge rate to the battery to prevent both overcharge and undercharge. 3. The cut-out relay disconnects the circuit between the battery and generator when the vehicle is not operating. In Fig. 3 is a voltage regulator mounted directly on the generator.

Electrical Design Factors: To design and make a satisfactory generator-battery application, all of the aforementioned factors must be considered.

Probably the foremost prerequisite for a well designed generator-battery system is the evaluation of the electrical factors. On a passenger car, for example, the electrical load is comprised of those units which normally require a continuous current supply, i.e., lights, radio, blower, ignition, etc. Units such as cigarette lighters, directional signals, starting motors, horns, and window lifts are classified as intermittent loads and do not alter the design of a generator-battery electrical system appreciably.

The contemplated total connected load should be measured or calculated as a single unit, and in a stabilized condition at a known ambient temperature. The voltage should be measured at the battery terminal of the generator-regulator. In this manner, all line-drop effect will be incorporated and the actual load the generator must supply will be known. The generator rating should be 10 to 25 per cent above the total continuous load demand to be able to provide current for battery charging and intermittent loads.

Since generator life is increased as the internal generator temperature is reduced, the operating ambient temperature and life expectancy must be known. On passenger cars, this life expectancy approaches 100,000 miles. The operating ambient temperatures range from subzero in the North to above 100 F in the Southwest. Since generator internal temperature is controlled by varying the current inversely with the temperature, it is obvious that the generator will be able to supply more current in the cooler climates of the North than for those of the South. A properly designed, temperature-compensated current unit in the generator-regulator will prevent generator overheating in this temperature range.

The importance of generator and regulator location in the vehicle becomes apparent, since the ambient temperatures of each must be correlated to adjust the current-limiting unit to the correct

setting. On some cars, ambient temperatures of generator and regulator are equal, while on others they vary in excess of 50 F. Fig. 4 illustrates the output range of a typical passenger-car generator operating in various ambient temperatures. The current limiter should follow the slope of this curve.

Nearly all vehicles encounter considerable battery discharge during cranking, engine idling, and low-speed driving. To recover these losses, the generator-regulator must be able to control the system voltage to insure a satisfactory battery-charging rate when the generator is operating. The voltage required for this charge varies inversely with the battery electrolyte temperature—and remember that the electrolyte remains much cooler when the battery is located in front of the radiator than when near the engine.

With an electrolyte temperature of 150 F, the voltage requirement of a nominal 12-v battery to maintain a 10-amp charge rate is approximately 12.75 v. The same battery with a 20 F electrolyte temperature requires 15.5 v for the 10-amp charge rate. When the battery electrolyte temperature falls under 20 F, there is no practical method of charging the battery on the vehicle. This is caused by the abnormally high voltage required, which exceeds the safe rating level for headlight and radio operation. When a vehicle operates in extremely cold weather, some provision must be made to maintain a reasonable battery temperature.

Battery electrolyte temperatures over 150 F approach a no-man's land in our present dc generator-battery systems. In other words a high charge rate to the battery can increase battery temperature, causing the charge rate to increase still more and result in thermal-runaway and a severely damaged battery. Fig. 5 illustrates the voltages required for a 10-ampere charge rate in a 60 per cent charged battery at various battery electrolyte temperatures. As the specific gravity rises, the charge rate will decrease unless the voltage is raised. Conversely, a higher charge rate will result if the applied voltage remains the same and the specific gravity is lower than that shown.

Since system voltage is controlled by the voltage-limiting unit in the generator-regulator, the voltage compensation curve should match the slope shown in Fig. 5. In addition, the ambient temperatures of each unit of the charging system must be known to assign the correct setting or voltage level to the voltage-limiting unit. If the voltage applied to the battery is too low, the battery will soon become discharged; if the voltage is too high, the resulting excessive charge rate can shorten battery life considerably.

The voltage-limiting device can only control the voltage level at its output terminal; consequently, caution must be exercised so that line drop is a minimum between the regulator and the battery and between the battery and ground. Excessive line drop will reduce the available charge and, in many types of automotive applications, result in a discharged battery.

City-Load Factors: It has long been the practice to regard rated output as the satisfactory measure of the ability of a generator to carry the electrical load. As previously stated, the rated output must exceed the total electrical load, exclusive of those items which are used intermittently for only a few seconds at a time. This fact must prevail in the most critical ambient temperature. For passenger cars equipped with air-conditioning, the critical temperature has been established at approximately 100 F since the majority of these are used in the Southwest.

On other cars, the extra power required for heater blowers plus the inability to charge the battery in extremely cold weather makes winter temperatures the more critical. It is obvious that these applications require different generators from the functional standpoint. The picture would be complete, electrically, if nearly all operation was at a speed above the full output point of the generator.

On truck applications, generator cut-in speed is of little importance since a large portion of operation is cross-country at medium to high speeds. However, this is not true of passenger cars. Many motorists use their cars for city driving only, and

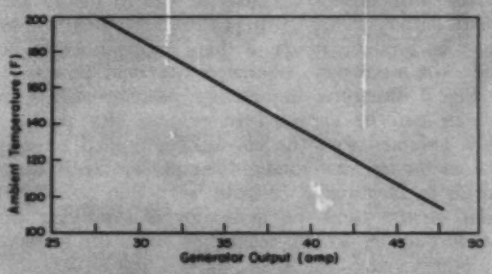


Fig. 4—Maximum continuous output values of a typical passenger-car generator versus ambient temperature of cooling air which will provide a safe internal generator temperature

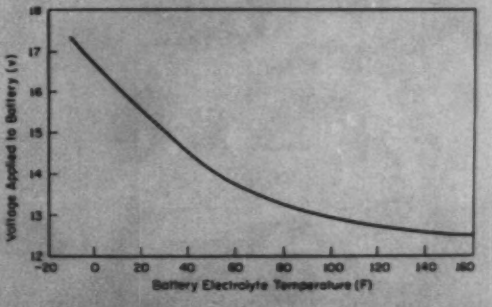


Fig. 5—Voltages required to maintain a 10-amp charge rate on a 60 per cent charged 12-v battery

these cars must be equipped with a generator which will keep the battery in a satisfactory state of charge. Typical city driving is considered to include operating time in both business and residential areas such as might be encountered by an owner who uses his car for daily transportation to work, with an occasional trip in city traffic at night. The generator should cut in at a speed low enough to allow any losses occurring during nighttime city driving to be recovered in the daytime. In other words, the capacity of a generator to carry the electrical load of the car under low-speed, city-driving conditions must be considered a second criterion in applying a passenger-car generator. This city-load factor changes from year to year as traffic congestion increases and driving habits change.

A typical car having a city night load of 30 amp and a city day load of 20 amp should be equipped with a generator capable of supplying at least 35 amp when full output is reached. Performance should be of such nature that the generator will supply 25 amp in normal city traffic without either charging or discharging the battery so that occasional night losses would be recovered in the daytime.

Vehicles used for door-to-door delivery, mail routes, police cars, and taxis require generators which will supply a charge-at-idle to insure sufficient battery charge. Alternators with rectifiers can now be used on many of these applications to provide the necessary low-speed electrical power.

Fig. 6 illustrates the average passenger-car speeds which can be expected in normal city traffic. If it is assumed that the cut-in of a typical generator occurs at approximately 10 mph and full output at 20 to 25 mph, it is easily seen that over 50 per cent of the time the generator is supplying little or no current. In the remaining time, the generator will supply current for the connected load and, in addition, provide a charge to recover some of the battery losses incurred at the lower speeds. Thus, modern driving habits have dictated that design consideration be given the city-load factor as well as the rated output.

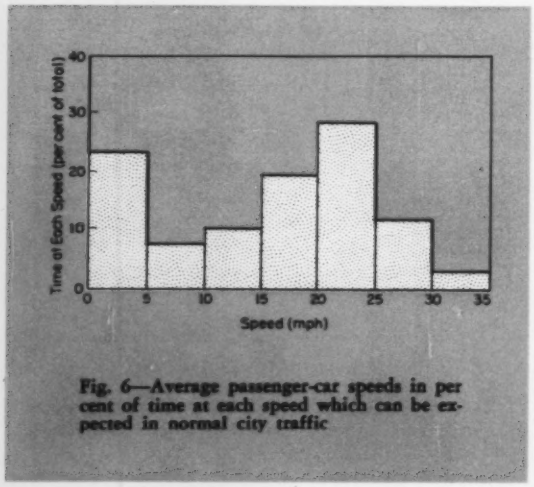


Fig. 6—Average passenger-car speeds in per cent of time at each speed which can be expected in normal city traffic

Physical Considerations: Generator mounting must receive careful consideration to utilize the full potential of the generator. As previously mentioned, more output will be available providing the generator is mounted in relatively cool air. However, if subjected to water splash or salt spray, it must be shielded and have corrosion resistance treatment of some nature. This also applies to all other electrical components. If shock or vibration is a problem as might be encountered on farm tractors, crawler tractors, and construction equipment, suitable shock mounting or vibration damping must be provided.

In some areas, dust seals and even nonventilated equipment is mandatory. Incidentally, the rated output of a nonventilated generator is approximately half that of a ventilated unit. The speed range, particularly the top speed, must be known to provide proper voltage and current control, to specify parts that will withstand the maximum centrifugal force to which they may be subjected, and to insure adequate commutation.

Maintenance Design Factors: Maintenance of various units in a generator-battery system is foremost in the minds of most commercial vehicle owners. Consequently, the desire for high mileage with a minimum of servicing influences the design of electrical equipment tremendously. The generator may incorporate sealed bearings, precision balancing of all rotating parts, and many other features used by the manufacturers of this type equipment.

Even on passenger cars, the accessibility of the units must be considered. For example, the generator, unless located in a convenient spot, will not receive adequate lubrication during normal vehicle servicing. When this occurs, steps must be taken to guarantee longer life without the recommended periodic service.

If at all possible, the battery should be located in a readily accessible location. This is the best insurance that proper attention will be given throughout the life of the battery. As previously pointed out, it is difficult to provide the proper charge rate to the battery if the electrolyte temperature is below 20 F or above 150 F. With this in mind, it is highly recommended that the battery be located so that the electrolyte temperature will remain in the 40 to 120 F range.

The battery is a perishable item, but long life can be expected with the correct regulated voltage, periodic servicing, reasonable ambient temperature, and an adequate generator to prevent deep cycling.

In conclusion, all design factors must be weighed in regard to cost versus the expected service and performance when designing a generator-battery system.

Selecting

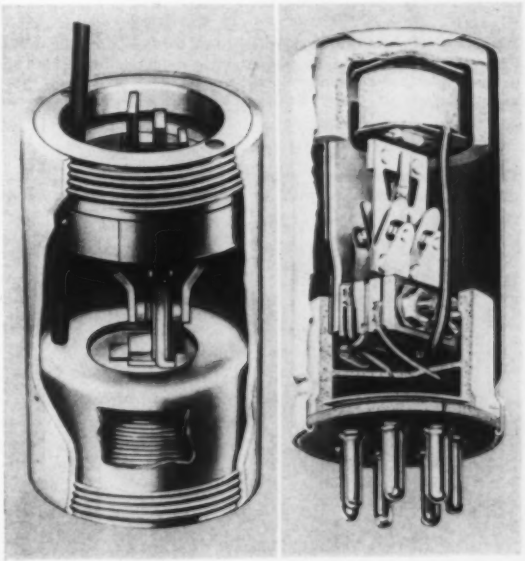
Vibrator and Dynamotor Power Supplies

Types of Conversion Devices
Electrical and Physical Considerations
General Areas of Application

By ROBERT C. RODGERS
Associate Editor
Machine Design

Fig. 1—Above—Designed for the Army Signal Corps, this vibrator is claimed to be the world's largest. Its over-all length is 6 in., and it has 20 power contacts and two driver contacts. It can operate on 6 or 12-v inputs and has a 200-w power rating

Fig. 2—Rugged interrupter-type vibrator at left operates satisfactorily after shocks of 9000 g. This steel-enclosed unit is ¾-in. in diam and 1¼ in. long. The 2⅞-in. long unit at right is a self-rectifying vibrator which can be designed to operate on 4, 6, 12, 24, or 32 v dc



Conversion of low-voltage dc to ac or high-voltage dc has been accomplished for many years with vibrator and dynamotor power supplies. These units find wide application as power supplies for communications equipment in vehicles, missiles, and aircraft. New transistorized "vibrator" power supplies are also available to perform these same conversion functions.

IN VEHICLES which carry electronic equipment in the form of radio transmitters and receivers, the big problem from the standpoint of the electric power supply is how to convert the low dc battery voltage to much higher voltages—usually dc. In ac power, one voltage can easily be converted to another with a transformer. In dc, the conversion device is not quite so simple. Three common types of dc-to-dc and dc-to-ac conversion devices are described here. Usually these power converters operate on batteries, although they can be designed to operate on practically any dc voltage.

Vibrator Power Supplies: A simple low-cost method the designer can use to convert dc power into higher voltage ac or dc is a vibrator power supply, Fig. 1 and 2. A vibrator is essentially a magnetically-operated, vibrating switch mechanism which chops dc power from a battery into square waves of ac. This ac voltage can then be raised by transformer action to a higher voltage. In communications equipment, there are two common types of

vibrators—nonsynchronous and synchronous. The nonsynchronous vibrator only converts dc power to ac. The synchronous vibrator is designed with an additional set of contacts which operate in synchronism with the first. The second set of vibrating contacts converts the ac voltage back to dc after the voltage has been raised to the desired level by transformer action. Often the synchronous type is called a self-rectifying vibrator and the nonsynchronous as simply an interrupter type. A so-called split-reed vibrator is a special form of the interrupter design.

In specifying a vibrator the important factors to consider are: 1. Vibrator input voltage. 2. Voltage and current requirements of the load. 3. Type of electrical load—capacitive, resistive, or inductive. 4. Type of duty—continuous or intermittent. 5. Life expectancy. 6. Environmental conditions. The type of electrical load is important since a vibrator works best on a capacitive load.

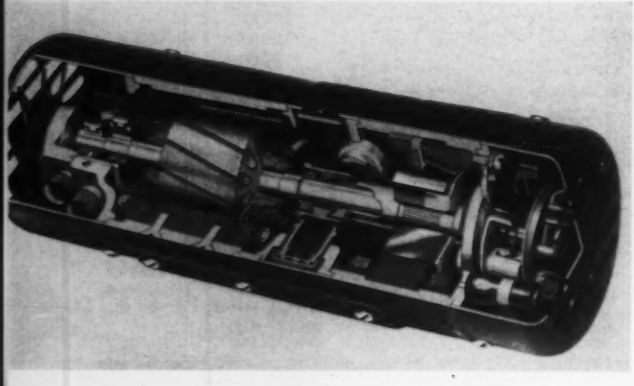
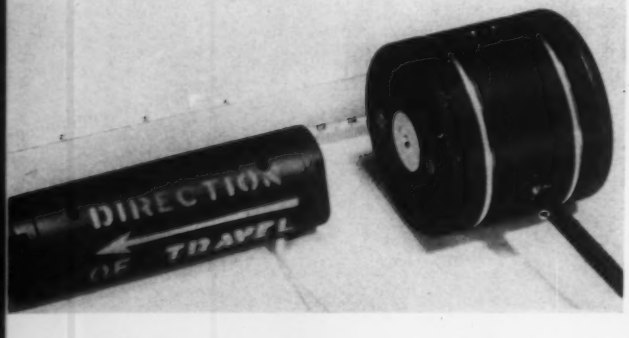


Fig. 3—Above—Combination dc-to-dc dynamotor and dc-to-ac inverter. Designed to power a radio transmitter and receiver, this power supply operates on 27.5 v dc and provides outputs of 250 v dc, 45 v dc, and 400-cycle 115-v ac

Fig. 4—Two miniature dynamotors for military applications. Unit at left is built to withstand high accelerations



Transistorized "Vibrator" Supplies: New fully transistorized "vibrator" power supplies are now available which can be substituted directly for the interrupter and self-rectifying electromechanical vibrators. These units are basically heavy-duty multivibrators designed with germanium power transistors. It is claimed that these units are more reliable, efficient, and rugged than mechanical vibrators.

Dynamotor Power Supplies: In design, a dynamotor is essentially a motor and a dc generator combined to function as a "dc transformer." A dynamotor has a low-voltage winding, or primary, and a high-voltage winding, or secondary, both wound on the same armature and shaft with a commutator provided for each winding. Two or three voltage outputs are provided on some of the larger dynamotors to supply high voltage and bias for radio transmitters. In this case, separate armature windings and commutators are provided for each output. The armature containing both input and output windings rotates in a field common to both. Some dynamotors are constructed for dual input voltages, such as 14 or 28 v, by the addition of another field winding. The two fields are connected in parallel for a 14-v input or in series for a 28-v input. Separate leads are provided for external connections to the primary source. In Fig. 3 is a cutaway of a combination dc-to-dc dynamotor and dc-to-ac inverter.

In specifying dynamotors, input and output voltage and current requirements are certainly important, but other electrical factors should be included, too. For example, voltage regulation and ripple factor should not be overlooked. As with vibrators, duty-cycle data should be given. Since many dynamotors are applied in aircraft, acceleration can materially affect the shape of the dynamotor, Fig. 4. In short, most environmental considerations along with cooling and mounting factors encountered in applying dynamotors are very similar to those met in dc generator applications.

ACKNOWLEDGMENT

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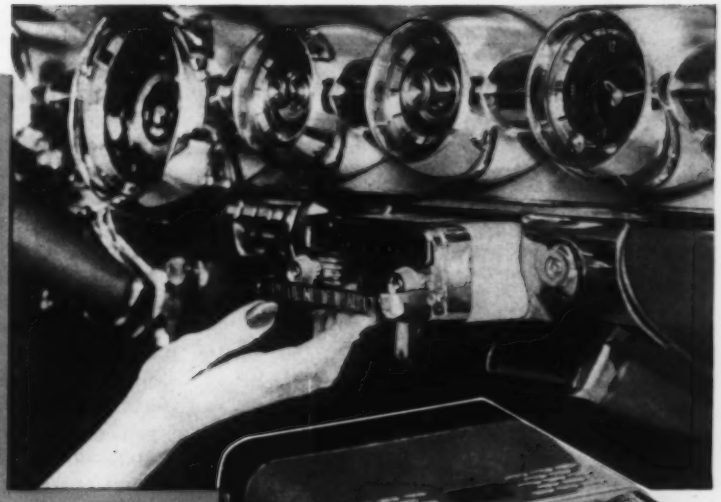


Fig. 1—Four 1.5-v penlight cells in series supply power to this combination car and portable radio. When radio is inserted in car dashboard, dry cells are cut out of the circuit and the radio uses the car electrical system, speaker, extra transistorized power supply, and outside antenna

Specifying and applying

Dry Cells and Storage Batteries

Basic types • Electrical characteristics
Physical properties • Environmental factors • Evaluation data

By CLARE E. WISE
Assistant Editor
Machine Design

Full use of battery capacity depends on how well the battery is matched to the device it operates. Careful evaluation of electrical requirements and expected environmental conditions are the key factors. When these are determined, an examination of the basic battery types can quickly determine the right battery for the job. Basic differences between batteries include: Capacity-to-weight and capacity-to-volume ratio, flatness of discharge curve, maximum discharge rate, probable service life, and, for storage batteries, charging characteristics and number of charge-discharge cycles available.

BATTERIES, by nature of their chemical reactions, are classified into two groups: 1. Primary (dry). 2. Storage (wet). In storage batteries the reaction is reversible; the battery can be recharged when partially exhausted by passing a current through it in the opposite direction. Primary batteries, not rechargeable, are used once and discarded. Basic "building block" in both types of batteries is the individual cell.

PRIMARY BATTERIES

Best known and most widely used of the primary batteries are the zinc-carbon "dry cell" (LeClanche cell) and the mercury cell. Other types are in use, notably the high-energy reserve types. Various experimental cells also show promise in special design applications.

Zinc-Carbon Batteries: First designed as a compromise to meet all existing uses, the familiar dry cell has been improved and modified in a number of ways to meet a wide variety of needs. One manufacturer produces a line of more than 100 types and sizes of cells and batteries—with 82 different terminal arrangements. Voltage ratings vary from

1.5 to 510 v. With this selection available it is usually possible to match the battery to a desired application.

A single dry cell, regardless of size, produces a nominal terminal voltage (open-circuit voltage) of 1.5 v. In almost all applications, it is necessary to use more than one cell, Fig. 1. For low-voltage, high-current applications, cells are connected in parallel; for high-voltage, low-current use, they are connected in series. Many applications require a combination of these two modes of connection.

Service capacity of dry-cells is expressed as the electrical energy output measured in a given unit of time on a specified discharge cycle and type of load, Fig. 2. The capacity will vary with:

1. Current drain
2. Intermittency of discharge
3. End-point voltage
4. Temperature
5. Storage period prior to use

The amount of energy available from a battery varies according to the load. Naturally, service life will be shortened if the load is too severe. On the other hand, if withdrawal of energy is too slow, shelf-deterioration, which is inherent in all dry cells, may reduce the available usable energy. Optimum performance is obtained at a point between these two conditions of service.

Dry cells are actually designed for intermittent service, Fig. 3. Continuous use is not inefficient, however, if the drain is sufficiently light as in some transistor circuits. Similarly, a relatively heavy drain may be permissible if the discharge periods are short or rest periods constitute a large proportion of the time.

One of the most important factors affecting service life of the battery is the minimum or cut-off voltage to which the battery is allowed to operate under load. The designer should make the minimum operating voltage as low as possible, Fig. 4. Low cut-off voltage can sometimes be provided through proper design of the battery. For example,

Checklist for Specifying Batteries

1. Application
   a. Type of device to be operated
   b. Primary battery
   c. Storage battery
2. Electrical Requirements
   a. Open-circuit voltage
   b. Starting voltage under load
   c. Cut-off voltage
   d. Current drain at starting voltage
   e. Current drain while operating
   f. Voltage tolerance allowable
   g. Operating service time
      Continuous
      Intermittent
      h. For intermittent service
         Time on
         Time off
3. Physical Requirements
   a. Dimensions
   b. Weight
   c. Terminal arrangement
      Type
      Number
      Location
4. Environmental Conditions
   a. Vibration
   b. Acceleration
   c. Shock
   d. Altitude
   e. Operating temperature range
   f. Storage temperature
   g. Duration of exposure to:
      Low temperature
      High temperature
5. Storage Battery Requirements
   a. Charging equipment
      For maintenance
      During operation
   b. Number of charge-discharge cycles
   c. Overall battery life
   d. Battery case material

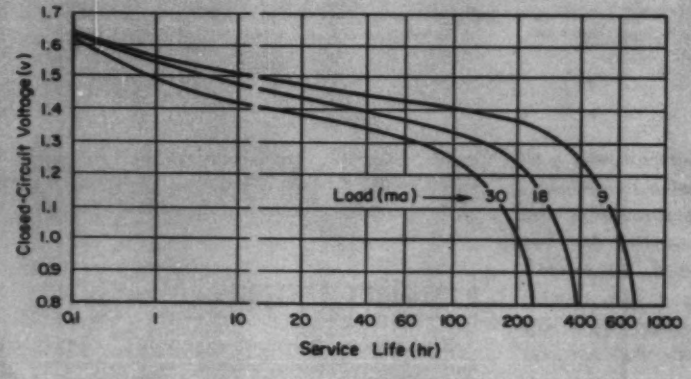


Fig. 2—Discharge characteristics of ordinary zinc-carbon flashlight battery (D cell) under three different constant-resistance loads. Cell was discharged 4 hr per day at 70 F. Current is in milliamperes measured at 1.5 v

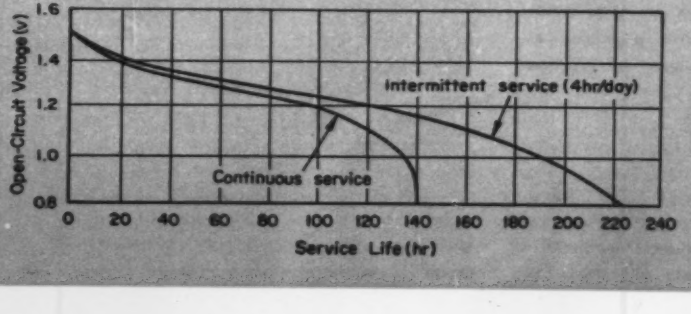


Fig. 3—Service life curves of a typical zinc-carbon A-size (penlight) cell under continuous and intermittent service

the electrical load might normally require 6 v, with a minimum satisfactory operating voltage of 4.8 v. If a 6-v battery having four cells in series is selected, the cut-off voltage per cell will be 1.2 v which is undesirably high. For economical operation, the battery should be provided with six cells in series, to permit a cut-off voltage per cell of 0.8 v. In this case a starting voltage of 9 v would be necessary.

Normal operating temperature for most dry batteries is 70 F. As with all batteries, service life at low temperatures is reduced because of retarded chemical action and the effects are most pronounced at heavy current drains. Most cells become inoperative at −10 F; freeze at −20 F. Exposure to low temperature does not cause permanent damage to cells; frozen batteries can be thawed and will return to their original condition.

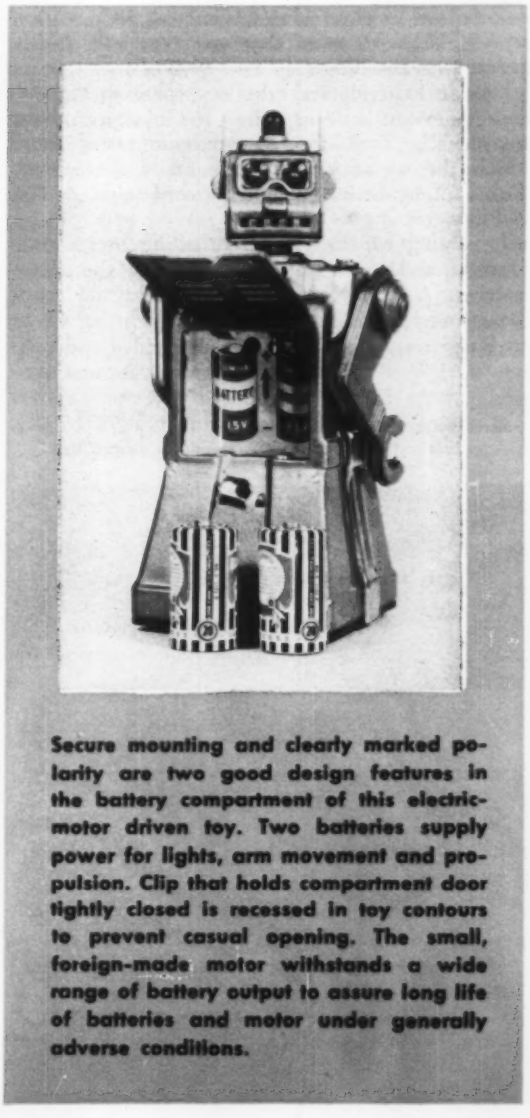
High temperatures accelerate chemical reactions within the cell and this increases both the useful current-producing reaction and the parasitic local reaction during idle periods. The net effect on total capacity delivered will depend on the balance between these two forces and will be different for various cell designs.

High limits of temperature for operation of dry cells are usually determined by the point at which seals flow or internal pressure expels the cell contents. This point varies with the size, chemical formula, and construction of the cell. Standard specifications call for a seal which will not flow at a temperature of 113 F during a static test in which the sealed surface is held vertical for a period of 24 hr.

In the design of portable equipment which may be operated either from enclosed batteries or regular power line, the placement of batteries in relation to a rectifier tube or other heat-producing circuit elements should be carefully considered. The battery is usually placed under the receiver chassis to prevent convection currents from carrying heat to the battery. Vents at top and bottom of cabinet backs ordinarily provide sufficient heat dissipation. Possibility of heat conduction to the battery must be considered where cabinets or containers are made of metal or other heat-conducting material. Placement of batteries near any source of heat radiation should be avoided.

The deterioration rate of dry cells during storage is ordinarily slow. Cells of good quality and reasonable size should remain usable for 2 yr. For small cylindrical cells, however, shelf life may only be a few months.

Mercury Cells: Widely used in transistor applications, mercury cells, Fig. 5, yield three to four times more energy per volume and weight than zinc-carbon cells. They have a much flatter discharge curve, Fig. 6, and operate better than the zinc-carbon in continuous-drain applications—especially where



Secure mounting and clearly marked polarity are two good design features in the battery compartment of this electric-motor driven toy. Two batteries supply power for lights, arm movement and propulsion. Clip that holds compartment door tightly closed is recessed in toy contours to prevent casual opening. The small, foreign-made motor withstands a wide range of battery output to assure long life of batteries and motor under generally adverse conditions.

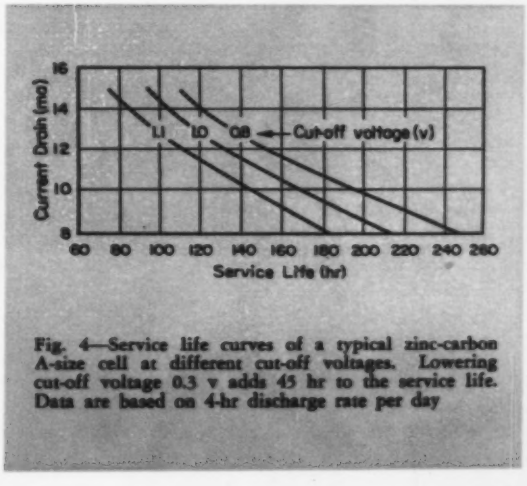


Fig. 4—Service life curves of a typical zinc-carbon A-size cell at different cut-off voltages. Lowering cut-off voltage 0.3 v adds 45 hr to the service life. Data are based on 4-hr discharge rate per day

voltage variation must be kept within narrow limits.

Nominal voltage of the cell is 1.345 v. Multicell batteries are made for high-voltage or high-capacity applications, including a selection of A and B batteries for portable radios and other electronic devices.

With the exception of low temperature, the mercury cell will withstand environmental extremes on a par with the zinc-carbon cell. Voltage drops rapidly at temperatures below 30 F. The high-temperature limit is set by the flow properties of the seal. Operation at 200 F is possible for a few hours.

Like the zinc-carbon units, mercury cells and batteries can be obtained in special shapes and sizes—a frequent design requirement in military equipment. For commercial use, however, standard cells that are readily available should always be specified.

Reserve Primary Batteries: Where very high power is needed on a "one-shot" basis, reserve primaries offer a convenient electrical power supply in a small package. Single-cell units slightly larger than a flashlight cell can deliver a current of 100 amp at 1.4 v for a few seconds. In most applications, current drain is considerably lower; life is measured in minutes or a few hours.

Three types are available: 1. Silver-zinc, Fig. 7. 2. Silver-chloride magnesium, Fig. 8. 3. Cuprous chloride magnesium.

All reserve units are stored dry—indefinitely—and require activation prior to use. The silver-zinc cell uses a special electrolyte; magnesium cells are immersed briefly in tap or sea water.

Solid-Electrolyte Batteries: Designed for very low-current applications, solid-electrolyte batteries, Fig. 9, are suitable for maintaining a charge on capacitors in electronic circuits. They will deliver up to 100 v per in. of battery, have an unlimited shelf life, and will operate in temperatures ranging from −65 to 165 F.

▶ STORAGE BATTERIES

Four types of storage batteries are readily available: 1. The familiar lead-acid battery. 2. The Edison or nickel-iron-alkaline battery. 3. The nickel-cadmium-alkaline battery. 4. The silver-zinc-alkaline battery which is relatively new.

Uses of the four battery systems are generally well defined by physical characteristics, performance, or cost, although more than one type will qualify in certain applications.

Storage batteries are rated according to ampere-hour and watt-hour capacity. Manufacturers have traditionally used the ampere-hour rating from which the watt-hour rating is easily determined. Both capacity ratings should be considered, as Fig. 10 illustrates.

In stating capacity, the rate of discharge, temperature, and cutoff voltage are given by the manufacturer. A typical 36-v, 18-cell industrial truck battery might thus be rated at 395 amp-hr, on a 6-hr discharge rate, at 77 F, to a recommended end voltage of 31.5 v. Variation of discharge rate and temperature can have a pronounced effect on capacity and service life, depending on the type of battery. Electrolyte specific gravity is also important.

Lead-Acid Batteries: Capacity of the lead-acid battery decreases rapidly as discharge rate increases because the plates take acid from the electrolyte faster than it is available from the main solution. The industrial-truck battery with a capacity of 495 amp at the 6-hr rate, will deliver only 275 amp at a 1-hr rate. Matching the battery to the expected discharge rate is thus important.

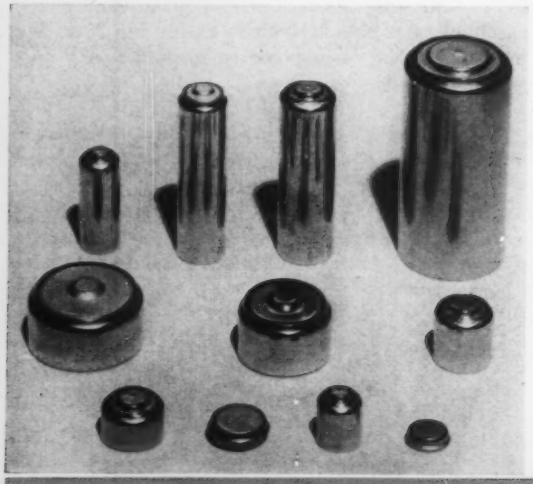


Fig. 5—Standard mercury cells. Largest cell is slightly smaller than an ordinary D-size flashlight cell. Smallest, for hearing aids, is 0.45 in. in diameter, 0.125 in. thick, and weighs 0.04 oz

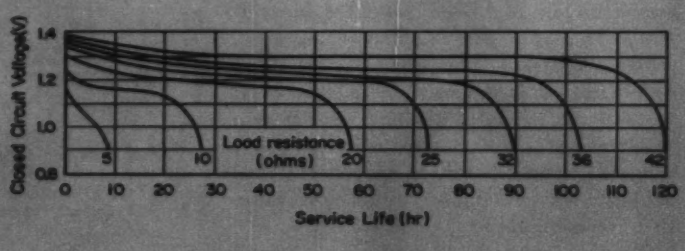


Fig. 6—Right—Discharge curves of a typical mercury cell under various loads shows slight voltage variation during the useful service life of the cell

Normal operating temperature of the lead-acid battery ranges from 60 to 80 F. Decreasing temperature decreases both the discharge voltage and capacity. Referring again to the industrial-truck battery, capacity will drop 60 per cent as temperature is lowered from 77 to 0 F.

Since strength of the electrolyte in lead-acid batteries varies directly with the charged condition of the battery, measuring specific gravity with a hydrometer and making proper temperature corrections is one of the simplest and most reliable means to determine the state of charge. The fully charged specific gravity varies according to battery make, but 1.270 to 1.280 is typical. Electrolyte gravity can be varied to meet special environmental conditions, according to manufacturer's directions. For example, batteries working under conditions of consistently high heat can be supplied with a specific gravity of 1.200. The capacity is decreased, however. For example, the capacity of a normal 495 amp-hr battery falls to 360 amp-hr with a 1.200 electrolyte.

Edison Batteries: Developed originally as a power source for electric automobiles and streetcars, Edison batteries are widely used today in industrial trucks, mine locomotives, and for standby or emergency power supplies.

The essential requirement of a traction battery is the ability to maintain capacity for a certain number of charge and discharge cycles, rather than maintaining capacity for a certain length of time. The Edison battery readily meets these requirements and is also relatively small in volume and weight.

Nominal voltage of a single cell is 1.2 v. In selecting a battery, the given number of cells would be determined by the voltage requirements. For example, a 36-v industrial truck would require a 30-cell battery.

The required ampere-hour capacity is determined by the average discharge rate in amperes multiplied by the number of hours of discharge before the battery is recharged. (Edison cells are rated at 5-hr discharge rate.) After the required capacity has been determined, cells are selected having a rated capacity of not less than 25 per cent higher. In service where the battery is used for emergency power it should have enough capacity for the maximum expected outage.

Freezing, at any state of charge, does not injure the battery and it is known to operate in industrial trucks exposed to −60 F temperatures. At the other extreme, overheating is minimized by free air space on all sides of all cells.

Edison batteries are mechanically durable. Cell containers are nickeled-steel with all seams welded. Plates and other components are also steel, and the battery can withstand considerable impact shock.

Relation of capacity to the rate of discharge differs from that of lead-acid batteries. Almost full capacity can be obtained, regardless of the rate of discharge,

Fig. 7—Silver-zinc primary battery provides powerful one-shot service. Open-circuit voltage of this particular battery is 35.2 v, nominal output is 142.5 w-hr. In typical missile application, the battery discharges 15 amp for 19 min at 30 v. Stored in dry state, battery can be activated in 0.1 sec by mechanism on topside.

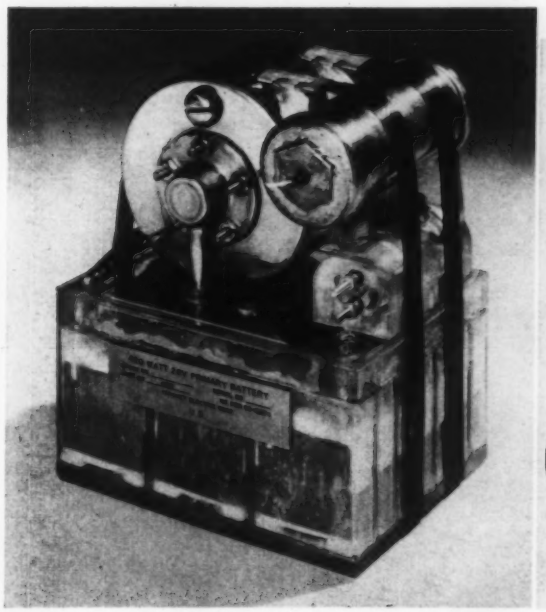
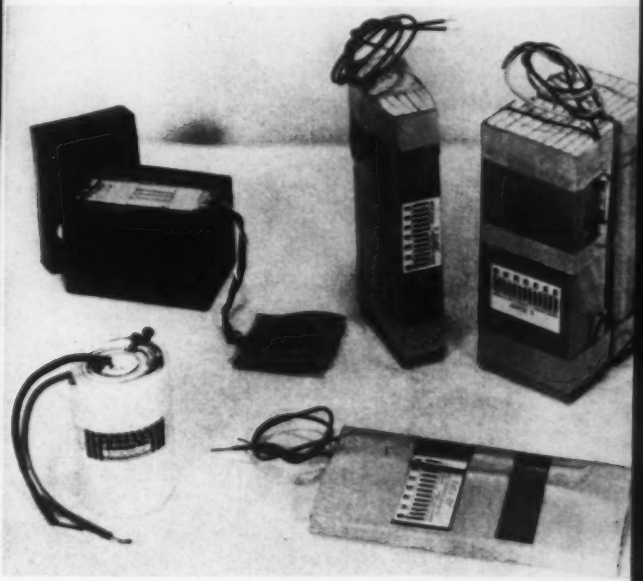


Fig. 8—Construction of water-activated reserve primaries permits extreme dimensional and voltage flexibility. Single cells have a nominal voltage of 1.5 v. Discharges at ambient temperatures of −40 F are possible if initial temperature of the battery is above freezing. High-temperature limit is about 150 F



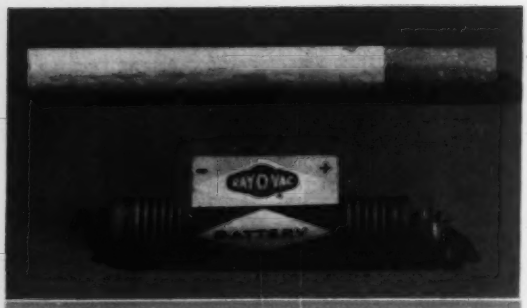


Fig. 9—Small solid-electrolyte battery consisting of multiple wafer-thin cells will supply high voltage at microamp current drains. Battery is used to charge capacitors and supply bias in electronic circuits

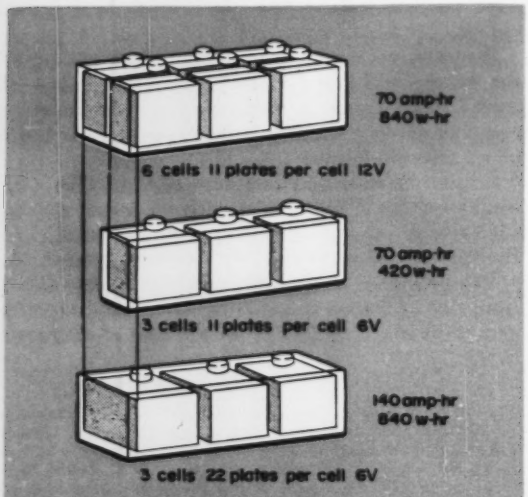


Fig. 10—A comparison of amp-hr capacity ratings alone can be misleading in selecting a storage battery. The 12-v battery illustrated has 11 plates in each of its 6 cells and a rating of 70 amp-hr. Since amp-hr capacity depends on weight of material and area of plates, a 6-v battery with the same number of similar plates in each of its 3 cells would also have a rating of 70 amp-hr. But, if the total of 66 plates used in the 12-v battery were divided equally between 3 cells, the unit would theoretically be a "22-plate" 6-v battery and would produce twice the capacity or 140 amp-hr. Thus, the extra "power" available from the 3 additional cells in the 12-v battery does not show up in the amp-hr ratings. When the effect of voltage is considered, the extra power becomes evident. (Watt-hours = ampere-hours x volts.) On this basis a 100 amp-hr, 6-v battery is rated at 600 w-hr; a 70 amp-hr, 12-v battery is rated at 840 w-hr. The power rating in w-hr makes possible a direct comparison of storage batteries.

although voltage is lower if current is higher than the normal 5-hr rate.

Capacity decreases at lower temperatures, but the relation does not follow a nearly proportional rate as with lead batteries. Edison batteries have a critical temperature which varies with the rate of discharge: Below this temperature output is small; above it, practically the full capacity of the battery is available.

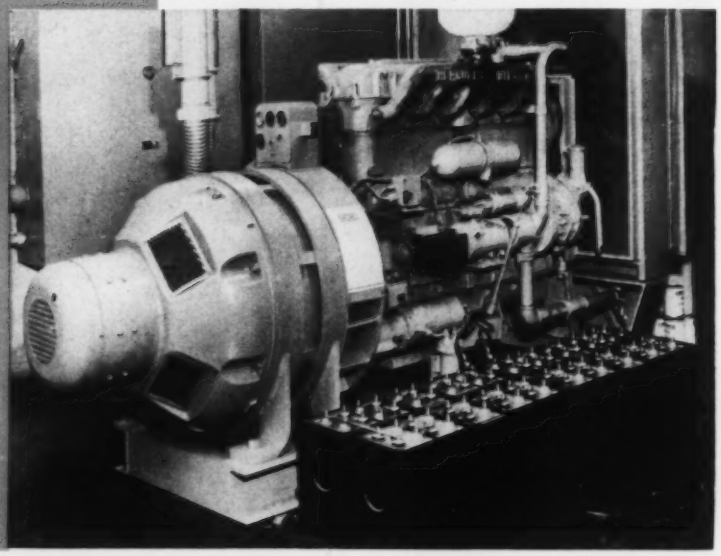
The battery can stand idle indefinitely without deterioration. It is necessary only to discharge the battery, short circuit it, store in a clean, dry place, and add water occasionally to maintain correct solution levels.

Nickel-Cadmium Batteries: Two distinct types of nickel-cadmium batteries are quantity produced. The older *pocket-plate* cell has been used in Europe for about 50 years, but received little attention in this country until late World War II. Since then, it has been complemented by development of the *sintered-plate* cell, and both types have rapidly gained a substantial market in military and commercial applications. They exhibit some rather impressive characteristics:

1. Longer life than any other rechargeable batteries, because of an all-steel construction and noncorrosive chemistry. Pocket-plate cells dating back to 1913 are still in use.
2. Normal operation in temperatures ranging from −40 to 165 F.
3. Extremely high surge currents with good voltage maintenance.

Pocket-plate batteries are used principally for emergency lighting, standby power, diesel-engine starting. Fig. 11, and switchgear tripping and closing.

Fig. 11—Pocket-plate, nickel-cadmium batteries provide automatic starting for this diesel-powered alternator. A total of 20 cells, rated at 1.2 v per cell, are assembled in four 5-cell batteries and connected in series to supply 24 v



Sintered-plate batteries are used for aircraft-engine starting and in missiles and other military and commercial electronic devices, Fig. 12. They provide higher discharge rates than the pocket-plate and have the further advantages of unlimited cycle life, smaller size, lighter weight, and ability to operate in greater temperature extremes. Single cells are available in capacities ranging from fractional amp-hr to 150 amp-hr. Certain high-rate cells, however, will supply momentary discharge currents up to 25 times their rated capacity. Cell sizes vary with capacity rating. The 150 amp-hr cell is approximately 9 in. high, 7 in. wide, and 3 in. thick. A 0.5 amp-hr cell is slightly larger than a postage stamp. Nominal voltage of both sintered-plate and pocket-plate cells is 1.2 v.

On a watt-hour basis, both types of nickel-cadmium batteries are heavier than nickel-iron or lead-acid batteries, but where high current drain is a basic design requirement, the nickel-cadmium cell comes in a much smaller, lighter package.

Silver-Zinc Batteries: This type of battery is especially suited for applications where: 1. Space or weight are of prime importance. 2. High currents are needed. 3. Long life is not important. The silver-zinc battery is relatively new and is being used effectively in aircraft and missile applications. It has the unique feature of being available as either a primary or storage battery.

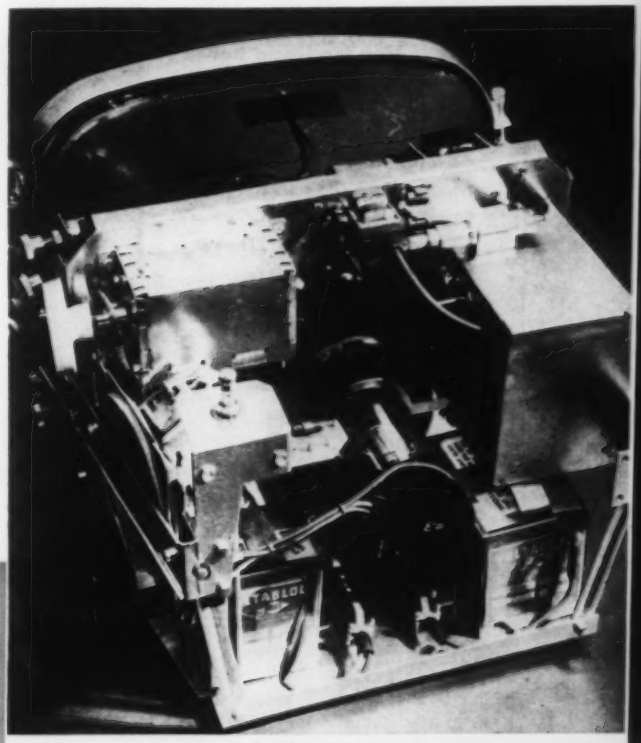


Fig. 12—Two sintered-plate nickel-cadmium batteries in this portable TV set supply 6 hr of playing time on one charge. Batteries can be recharged in 2 hr by plugging the set into house current. They have a life expectancy of 2000 cycles

Fig. 13—Smallest silver-zinc cell, slightly larger than a postage stamp, is rated at 0.1 amp-hr and will supply a peak pulse discharge of 3 amp. The larger 200 amp-hr cell will discharge 200 amp for 1 hr at better than 1 v. It will provide a peak pulse discharge of 3000 amp. The cell is 11 in. high, 5.8 in. wide, and 1.3 in. thick

On an ampere-hour basis, the silver-zinc cell is 4 to 6 times smaller and lighter than lead-acid, nickel-iron, or nickel-cadmium cells, Fig. 13. It has a shorter life, however, and is obviously more expensive.

Because the cells have definite application in widely diversified fields, ranging from 1 min rates to 1 yr rates of discharge, several types of cell construction and capacity have been developed. Cells range from 0.1 to 300 amp-hr capacity, and are designed for three types of service:

1. High-rate (1 to 30 min) cells designed for 10 to 20 cycles over a period of 3 to 6 mo. These give the highest potential outputs, so do not have the maxi-

Lead-acid and nickel-iron (Edison) batteries are widely used in materials-handling vehicles. This 5000-lb capacity lift truck has a 36-v lead-acid battery rated at 540 amp-hr or 18.9 kw-hr. Battery selection depends on careful evaluation of the electrical demands of the truck in terms of the expected work cycle. These factors are considered:

1. **Weight of truck**
2. **Average load weight**
3. **Average trip length**
4. **Ramp elevation**
5. **Number trips per shift**
6. **Average lifting height**
7. **Number lifts per shift**
8. **Frequency of acceleration**

mum plate-separator protection. Internal resistance is at a minimum.

2. Medium-high-rate (30 min to 5 hr) cells are constructed with additional protection to give 40 to 50 cycles over a period of 6 to 9 mo. These are used where high rates are required as well as longer life.
3. Low-rate (one hr and over) cells are constructed with the maximum protection to give up to 150 cycles, and on special construction, up to 300 cycles over a 1-yr period. Over extended periods, there is a drop-off in capacity after about 100 cycles. This is at a minimum with continuous cycling and a maximum with long intervals between cycles.

Silver-zinc cells in these categories have supplied electric power for vibrators, dynamotors, radio, television portable cameras, movie cameras, telemetering, instrumentation, missiles, ordnance equipment, model planes and boats, and aircraft.

Cells can be charged in ½ hr, but the output will be about 60 to 70 per cent of normal. At rates of 2 to 3 hr, it is possible to obtain 90 to 95 per cent capacity from high and medium-rate cells. Low-rate cells are charged to not less than the 5-hr rate for best performance.

As in other types of storage batteries, low temperatures affect discharge voltage and capacity. This is not as pronounced at higher rates of discharge, since the cell heats itself on discharge. At low rates voltage drops off at about −20 F. Performance of cells at −60 F can be obtained, however, by short-circuiting the battery to warm it up. This is accomplished by using a current-limiting relay which opens the circuit when the current reaches a certain value. Normal operation is then obtained.

In certain applications, where the voltage tolerance over wide temperature ranges must be limited in the range of 1 to 5 per cent, the battery should be maintained at a fixed temperature by heaters.

ACKNOWLEDGMENTS

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C & D Batteries, Inc. ..... Conshohocken, Pa.
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Delco Remy Div., General Motors Corp. (Fig. 10) ..... Anderson, Ind.
Thomas A. Edison Industries ..... West Orange, N. J.
Electric Storage Battery Co. ..... Philadelphia, Pa.
Gulton Industries, Inc. ..... Metuchen, N. J.
K-W Battery Co. ..... Skokie, Ill.
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Yardney Electric Corp. (Fig. 7, 13) ..... New York, N. Y.

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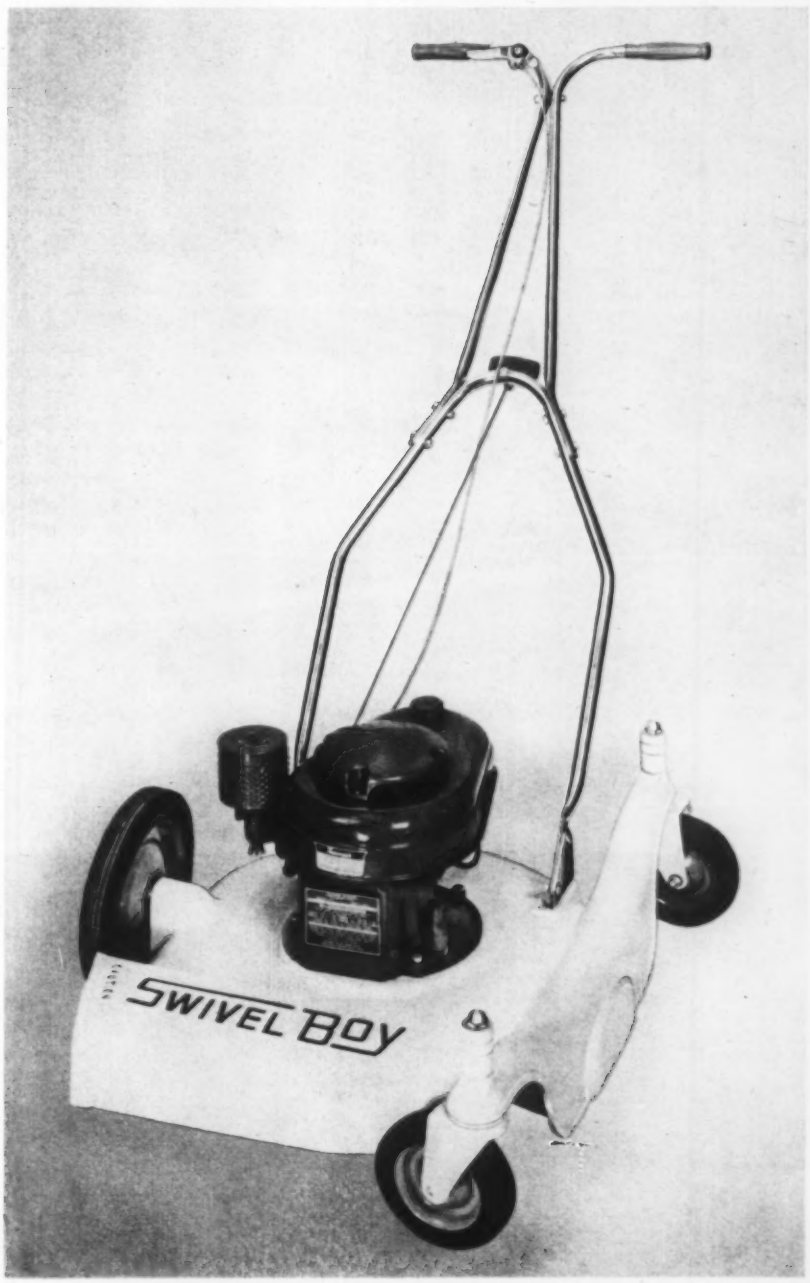
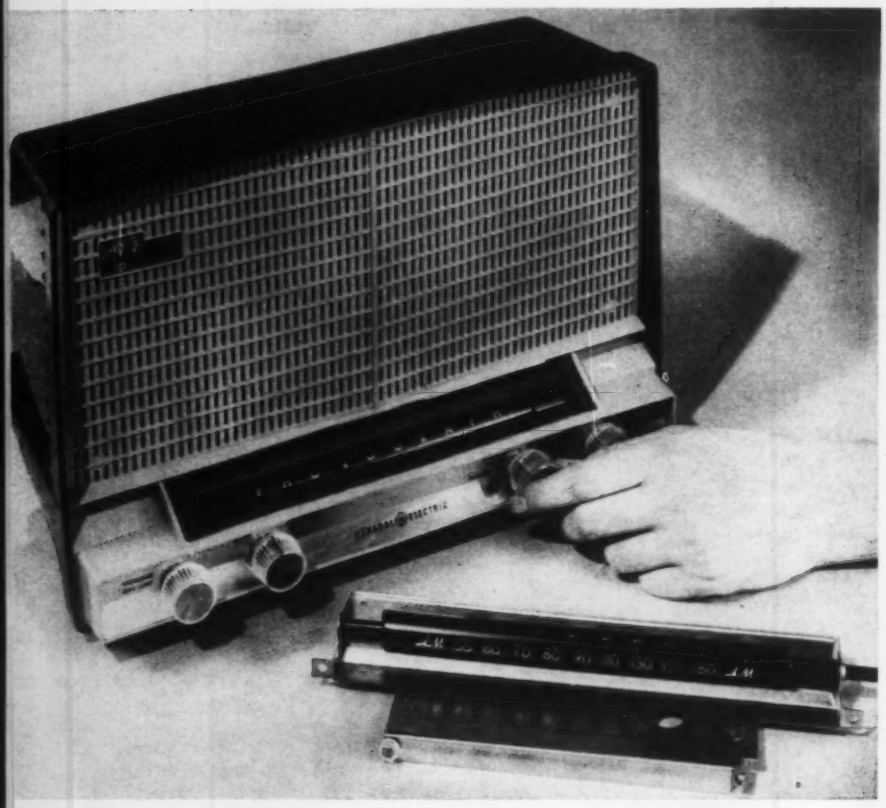
Swivel Wheels on One Side of Mower Increase Maneuverability

QUICK CHANGES IN DIRECTION of travel are easily accomplished with the new Swivel Boy rotary power mower. Designed and engineered by Alex Smith, Seminole Mower Co., Decatur, Ill., the machine rolls on two ball-bearing swivel wheels and one larger rigid wheel. The in-line placement of the swivel wheels permits operator to change mower-blade path without lifting the wheels off the ground. The swivel action also allows the mower to be turned through a complete 360-degree circle around a tree or pole with little effort.

The larger rigid wheel mounted in the center of the opposite side of the machine prevents scalping of high crowns and terraces and, at the same time, provides positive control of travel direction.

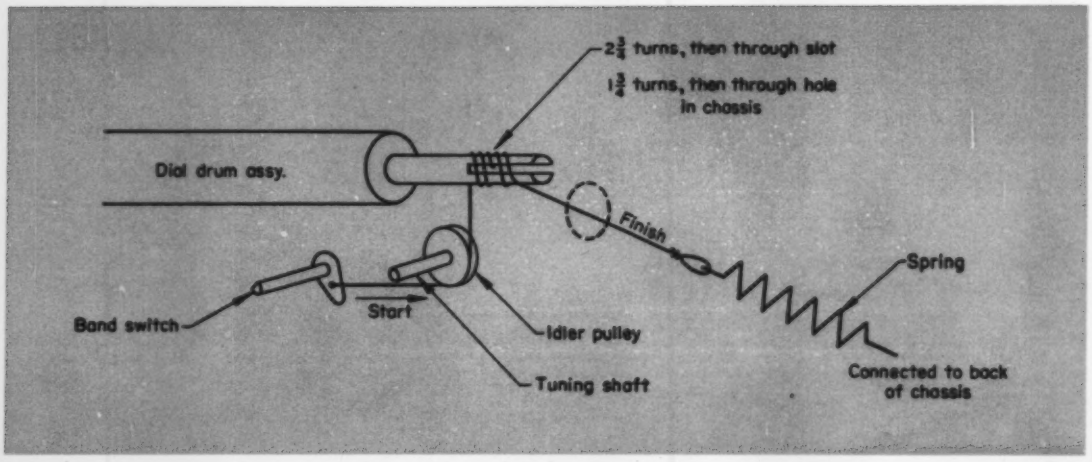


Multiple Scales on Cylindrical Tube Minimize Dial-Setting Errors



FOUR DIAL SCALES spaced at 90-degree intervals on a cylindrical drum or tube allow using larger markings in the design of a new G-E combination radio-phonograph. The tube, which is made of Ancorene extruded plastic by Anchor Plastics Co., Long Island City, N. Y., is printed with a separate scale for AM, FM, FM-AFC reception along with the word "phonograph."

LOW-COST STRING DRIVE, which is moved by a band-switch knob on the front of the cabinet, rotates tube through 1/4-turn steps. For each type of reception, only one dial scale with large, easy-to-read figures is visible. The scale takes up a space less than 1 in. wide. The plastic tube is only 0.7 in. in diameter.



A simplified tabular method for

Torsional Vibration Analysis

of multiple-rotor shaft systems

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University of Technology
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MECHANICAL systems in the form of a rotating straight shaft with flywheel, pulleys, gears or other "rotor" elements can develop severe, or even destructive, torsional oscillations in operation. If there are s rotor elements and the mass moment of inertia of the shaft is negligible compared to the moments of inertia of the individual rotors, the system is considered to have, internally, $s-1$ degrees of freedom or natural modes of vibration. To avoid dangerous resonance conditions in the system, it is necessary to know the frequencies of oscillation associated with these modes.

For an s-rotor system, direct calculation of the frequencies from the physical properties of the system leads to an equation of $s-1$ degree. Thus, this method of solution is practical only for 2 and 3-rotor systems, necessitating the use of some form of iterative "gradual approach" procedure when number of rotors s exceeds 3.

Both analytical[1,2] and graphical[2] techniques have been developed for this purpose. Perhaps, the most widely used approach is the Holzer method which is based on a tabular form of calculation. It has some drawbacks, however, in that speed of solution depends upon the accuracy of arbitrary assumptions of frequency values. This article presents a new method of attack which simplifies the "homing-in" operation and reduces to a minimum the time and effort of "gradual approach" calculations.

Basic Concepts: Symbols, terminology and notation convention used here are defined in *Nomenclature* and Fig. 1.

If the positions of the nodes in a vibrating system are known, vibration frequencies can be determined from

$$f = \frac{1}{2\pi}\sqrt{\frac{G\,I_p}{I^e l}} = \sqrt{\frac{G\,I_p}{K}} \qquad (1)$$

regardless of whether the corresponding node, n,

[1]References are tabulated at end of article.

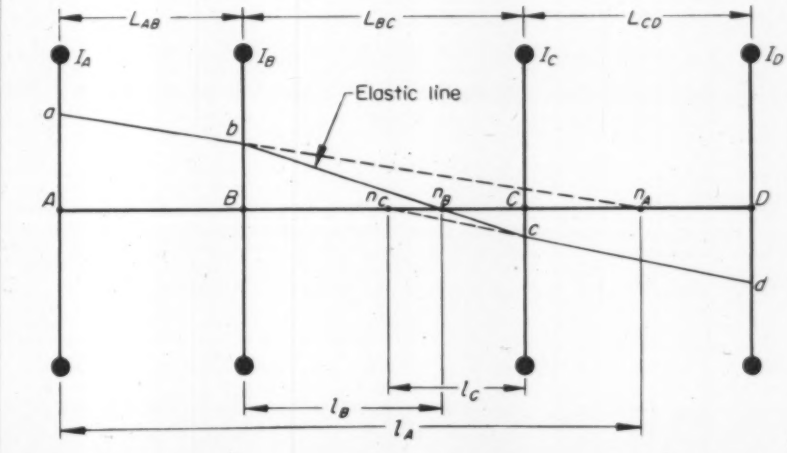


Fig. 1 — Typical in-line 4-rotor system showing fundamental relationships and nomenclature for torsional vibration analysis

Nomenclature

A uniform-diameter shaft with four attached rotor elements, *A*, *B*, *C*, and *D*, is depicted schematically in Fig. 1. This system is assumed to be producing torsional vibrations of lowest natural frequency, as indicated by the shape of the elastic line.

Moments of inertia of the individual rotors are designated by subscript. Thus, I_A is the actual mass moment of inertia of rotor *A*, I_A^e is the effective or equivalent moment of inertia at point *A*. For referred effective moments of inertia, a double subscript notation is used. Thus, I_{AB}^e is the effective moment of inertia at position *A* referred to position *B*.

Distances between specific rotors are also identified by a double subscript; L_{AB}, for example, is the distance between rotors *A* and *B*.

In Fig. 1, line *abcd* represents the development of the "elastic line" in which the intercepts *Aa*, *Bb*, *Cc* and *Dd* represent to some scale the amplitudes of oscillation of the respective rotors. The "nodes" or points of intersection of the segments of the elastic line (extended, if necessary) with the center line of the system are distinguished by the subscript for the left-hand rotor of the corresponding portion of the shaft. A node which is located on the elastic line proper is defined as a "physical" node. Such a node (n_B in Fig. 1) determines a cross-section of the shaft which does not take part in the vibration. If a system oscillates at its lowest natural frequency, then the elastic line shows only one physical node. The second natural frequency is associated with two physical nodes, and so on.

A node which lies on an extended portion of the elastic line is called a "mathematical" node (n_A and n_C in Fig. 1). The "nodal distance," which is the distance between a rotor and its corresponding node, is considered positive if the node is to the right of the rotor (l_A and l_B in Fig. 1), and negative if it is to the left (l_C in Fig. 1).

Symbols

f_1, f_2, f_3 = First, second, and third natural vibration frequencies, respectively, cps
G = Modulus of rigidity (shear modulus) of shaft material, psi
I = Actual mass moment of inertia of rotor element, lb-in.-sec^2
I^e = Effective or equivalent moment of inertia, lb-in.-sec^2
J_p = Polar moment of inertia of shaft cross-section, in.^{4}
K = Frequency factor, lb-in.^{2}-sec^2
L = Distance between rotor elements, in.
l = Nodal distance, in.
s = Number of rotor elements in system

is defined as a physical or mathematical node. As implied previously, nodal distances can be calculated directly only in 2 or 3-rotor systems. For multiple-rotor systems where $s>3$, a gradual approach method of solution is required.

The method described in this article is based on the assumption of an arbitrary value for nodal distance l_A. Degree to which the result obtained deviates from a theoretical criterion, Fig. 2, is then determined. By repetition of the process with adjusted values for l_A, this deviation, or error, can be decreased as much as desired.

With this method, calculations are most conveniently carried out in a tabular form. General details of the solution procedure are given in *Method of Calculation* and Table 1. Application of the technique for torsional vibration analysis of a typical 4-rotor system is illustrated in Example 1.

Branched Systems: So far, attention has been given

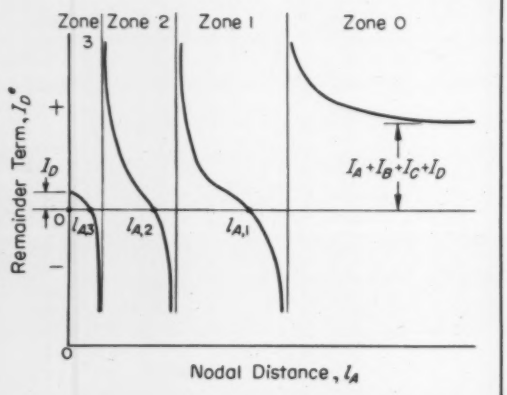


Fig. 2—Relationship of assumed nodal distances to remainder terms, or error, in tabular analysis of 4-rotor system for different modes of torsional vibration. Zone number corresponds to number of physical nodes in the system

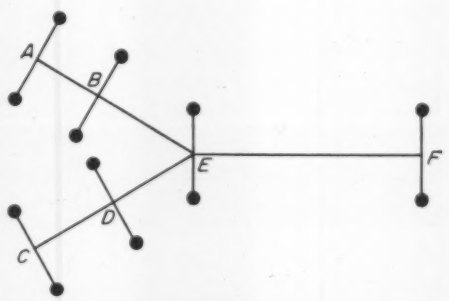


Fig. 3—Typical branched multiple-rotor system. Torsional vibration characteristics of such systems can be readily analyzed by the tabular method presented in the text (Example 2)

only to the analysis of simple or in-line systems. The method can also be readily adapted to calculation of frequencies of branched systems, such as the one shown in Fig. 3.

First, a value for l_A or K is assumed. Then, starting at free end A of one branch, the same calculation procedure as used for simple systems is followed for this branch until the value of I_{BE}^{ϵ} is obtained. The sequence of analysis is then interrupted and a separate similar series of calculations is completed for the second branch, beginning at free end C. These calculations proceed in the same manner as before, until the value of I_{DE}^{ϵ} is established. Total equivalent moment of inertia I_E^{ϵ} at the junction of

Method of Calculation

General form of vibration calculations is given in Table 1 for a 4-rotor system such as depicted in Fig. 1. For this tabulation, the following step-by-step procedure is recommended.

1. Complete columns I and II, filling in the physical details—actual mass moments of inertia (I) of, and distances (L) between, the rotor elements—of the system.

2. Begin solution at left-hand end of system by filling in value of effective moment of inertia of left-hand rotor A (item 1, column III). If this end of the system represents the starting point, the only moment of inertia is I_A and, $I_A^{\epsilon} = I_A$.

3. Assume value of nodal distance l_A (item 1, column IV).

4. Compute frequency factor $K = I_A^{\epsilon} l_A$ (item 1, remarks).

5. Fill in value of nodal distance $(l_A - L_{AB})$ for referred effective moment of inertia I_{AB}^{ϵ} (item 2, column V).

6. Compute referred effective moment of inertia I_{AB}^{ϵ} (item 2, column VI). This quantity represents the effective value of I_A^{ϵ} at position B; that is, it will give the same frequency value and node point at position B as I_A^{ϵ} at position A.

7. Compute total effective moment of inertia I_B^{ϵ} at rotor B (item 3, column III). This value is given by the sum of referred and actual moments of inertia at rotor B.

8. Compute nodal distance l_B for "equivalent" rotor B (item 3, column IV).

9. Continue calculations, proceeding in order by item and column, to complete table and to determine effective moment of inertia of right-hand rotor. For the 4-rotor system of Fig. 1, this value becomes I_D^{ϵ} (item 7, column III).

10. Check accuracy of assumed value for nodal distance l_A. If the correct distance was chosen, then the values of referred and actual moments of inertia at the right-hand rotor, I_{CD}^{ϵ} and I_D, would, theoretically, be numerically equal. However, the referred moment of inertia, I_{CD}^{ϵ}, will always have a negative value in this solution because of the sign convention employed with nodal distances. Thus, the criterion for checking solution results is: Total effective moment of inertia of the right-hand rotor equals zero. For the 4-rotor system of Fig. 1 then, $I_D^{\epsilon} = I_{CD}^{\epsilon} + I_D = 0$.

Generally, with nodal distance l_A assumed at random, the total effective moment of inertia at the right-hand rotor, I_D^{ϵ}, will have either a positive or negative value. If these "remainder terms" are plotted against the corresponding nodal distances (l_A), a series of s well-defined zones is obtained. A plot of this type for a 4-rotor system (Fig. 1) is shown in Fig. 2. For convenience, the zones are numbered from 0 to s-1; the zone number indicates the number of physical nodes, or mode of vibration, corresponding to any nodal distance l_A within that zone. Zone 0 need not be considered because the nodal distances are far too large.

Within the other zones, however, a negative remainder term for I_D^{ϵ} indicates that assumed nodal distance l_A is too large and a positive remainder term that it is too small.

Thus, the result of the first calculation attempt clearly indicates the direction of approach to the correct solution for repeat calculations.

Table 1—Form of Calculations

Item	I I	II L	III I^{ϵ}	IV l	V $l - L$	VI I^{ϵ} (referred)	Remarks
1	I_A		$I_A^{\epsilon} = I_A$	l_A (assumed)			$K = I_A^{\epsilon}(l_A)$
2		L_{AB}			$l_A - L_{AB}$	$I_{AB}^{\epsilon} = \dfrac{K}{l_A - L_{AB}}$	
3	I_B		$I_B^{\epsilon} = I_{AB}^{\epsilon} + I_B$	$l_B = \dfrac{K}{I_B^{\epsilon}}$			
4		L_{BC}			$l_B - L_{BC}$	$I_{BC}^{\epsilon} = \dfrac{K}{l_B - L_{BC}}$	
5	I_C		$I_C^{\epsilon} = I_{BC}^{\epsilon} + I_C$	$l_C = \dfrac{K}{I_C^{\epsilon}}$			
6		L_{CD}			$l_C - L_{CD}$	$I_{CD}^{\epsilon} = \dfrac{K}{l_C - L_{CD}}$	
7	I_D		$I_D^{\epsilon} = I_{CD}^{\epsilon} + I_D$				Criterion: $I_D^{\epsilon} = 0$

the branches is the sum of the two referred moments of inertia and the actual moment of inertia at that point:

$$I_E^e = I_{BE}^e + I_{DE}^e + I_E \qquad (2)$$

When the value of I_E^e is determined, calculations are continued from the junction of the branches to the end of the system at F. As in the case of simple systems, remainder term I_F^e should be zero. Details of a typical branched-system vibration analysis are given in Example 2.

Initial Assumptions: Value of I_A or K may be initially assumed at random. Although the result obtained with this value may be far off the mark, it will indicate the required direction of approach. The true value of I_A can be established in a few

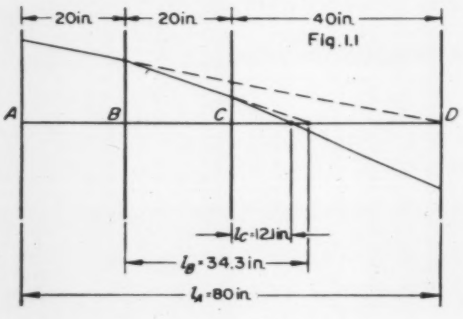
Example 1—In-Line Multiple-Rotor System

A uniform-diameter shaft has four attached rotors (Fig. 1). Modulus of rigidity of the shaft material G = 12,000,000 psi. Shaft diameter is 2 in., giving J_p = 1.57 in.[4] Physical details of the system are, Fig. 1.1: I_A = 10 lb-in.-sec², I_B = 10 lb-in.-sec², I_C = 10 lb-in.-sec², I_D = 30 lb-in.-sec², L_{AB} = 20 in., L_{BC} = 20 in., L_{CD} = 40 in. Determine the three natural frequencies of torsional vibration of the system.

1. Lowest Natural Frequency: For the first trial solution, assume nodal distance l_A = 80 in. From *Method of Calculation* and Table 1, I_A^e = 10 lb-in.-sec², and K = 10(80) = 800. Calculations for the first solution are given in Table 1.1. Corresponding elastic line is shown in Fig. 1.1.

Table 1.1

l	L	I^e	l	$l - L$	I^e (referred)
I_A = 10		I_A^e = 10	l_A = 80		
	L_{AB} = 20			$l_A - L_{AB}$ = 60	I_{AB}^e = 13.3
I_B = 10		I_B^e = 23.3	l_B = 34.3		
	L_{BC} = 20			$l_B - L_{BC}$ = 14.3	I_{BC}^e = 55.9
I_C = 10		I_C^e = 65.9	l_C = 12.1		
	L_{CD} = 40			$l_C - L_{CD}$ = −27.9	I_{CD}^e = −28.7
I_D = 30		I_D^e = +1.3			

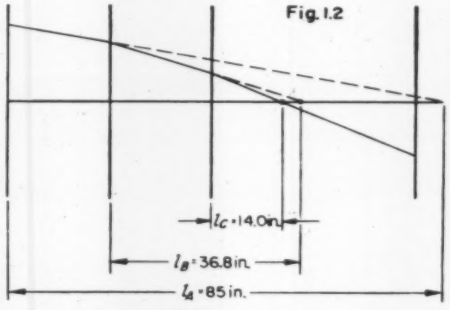


In this first solution, the value of I_D^e is positive, indicating that the assumed value of I_A is too small. The elastic line shows, however, that this assumed value is in the correct zone (one physical node).

For a second trial calculation, assume I_A = 85 in. This solution, following the same procedure as before, gives l_B = 36.8 in., l_C = 14.0 in. and I_D^e = −2.7 lb-in.-sec². Corresponding elastic line is shown in Fig. 1.2.

Here again, the assumed value of I_A is in the correct zone. However, as indicated by the negative value of I_D^e, it is too large.

Correct nodal distance, as verified by a third trial calculation, is $l_{A,1}$ = 81.7 in. where the number in the subscript identifies the mode of vibration. From Equation 1, first or lowest natural vibration frequency is



$$f_1 = \frac{1}{2\pi}\sqrt{\frac{12(10)^6(1.57)}{10(81.7)}} = 24.2 \text{ cps}$$

2. Second Natural Frequency: For a first trial calculation of the second natural vibration frequency of the 4-rotor system, assume I_A = 15 in. Completing the tabular solution gives l_B = −7.5 in., l_C = 33.0 in. and I_D^e = +8.6 lb-in.-sec². The corresponding elastic line appears in Fig. 1.3.

attempts due to the rapid convergence of the method.

This characteristic of the method has another advantage. Since nodal distances l become smaller as natural frequencies go higher, fewer repeat calculations are, in general, necessary for evaluation of the complete frequency "spectrum" of a system than with other methods, notably Holzer's.

Occasionally it is possible to replace the system being analyzed by a much simpler system for which the frequency factor can be easily determined. In this manner, an approximate value for the frequency factor of the actual system can be readily found. Such an approach is illustrated in Example 3.

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2. Thomas Bevan—*The Theory of Machines*, Longmans, Green & Co., London, 1942, pp. 516-527.

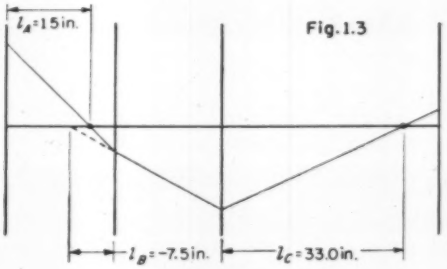

Fig. 1.3

These results show that the assumed value of l_A is in the correct zone but is too small.

For the second trial calculation, assume l_A = 15.5 in. Solution gives l_B = −6.3 in., l_C = 37.6 in., and I_{D^e} = −44.6 lb-in.-sec². Elastic line is shown in Fig. 1.4.

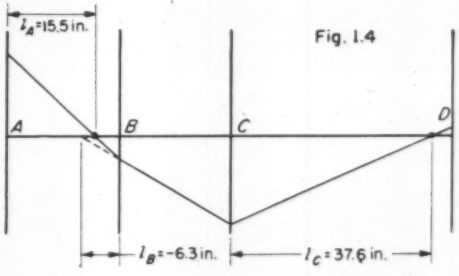

Fig. 1.4

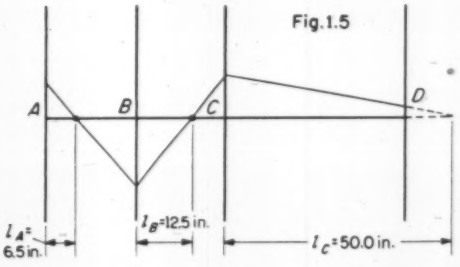

Fig. 1.5

Here, the assumed value is in the correct zone but is too large.

From the two trial calculations, it is apparent that 15 in. < $l_{A,2}$ < 15.5 in. Since the difference in frequency values for these two assumed nodal distances is only about 1.5 per cent, further refinement of the solution would hardly seem necessary. However, as verified by a third trial calculation, correct solution is $l_{A,2}$ = 15.2 in. From Equation 1, second natural vibration frequency is

$$f_2 = \frac{1}{2\pi}\sqrt{\frac{12(10)^6(1.57)}{10(15.2)}} = 56 \text{ cps}$$

3. THIRD NATURAL FREQUENCY: For a first trial, assume l_A = 6.5 in. Tabular solution gives l_B = 12.5 in., l_C = 50 in., and I_{D^e} = +36.5 lb-in.-sec². The corresponding elastic line is shown in Fig. 1.5.

Although I_{D^e} has a positive value, it is apparent from an inspection of the elastic line that the assumed value of l_A is too large. The elastic line shows only two physical nodes, indicating that the assumed nodal distance falls in Zone 2 (Fig. 2) instead of Zone 3 as it should.

For a second trial, assume l_A = 6.4 in., which gives l_B = 12.1 in., l_C = 33.8 in., and I_{D^e} = +17.7 lb-in.-sec². Elastic line is shown in Fig. 1.6.

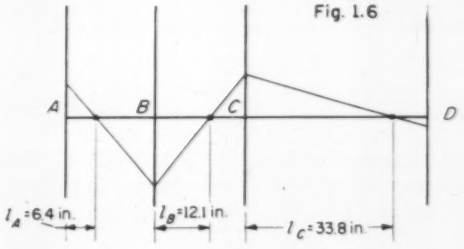

Fig. 1.6

The positive value of I_{D^e} plus the shape of the elastic line (3 physical nodes) indicate that the assumed value of l_A is in the correct zone but is too small.

From the trial calculations it has been established that 6.4 in. < $l_{A,3}$ < 6.5 in. Difference in the corresponding frequency values for these two assumed nodal distances is less than 1 per cent, eliminating the need for any further trial attempts. However, as a matter of interest, further refinement of these calculations shows that the boundary between Zones 2 and 3 (Fig. 2) corresponds to l_A = 6.45 in. (I_{D^e} = ∞). Correct nodal distance is $l_{A,3}$ = 6.43 in. (I_{D^e} = 0). From Equation 1, third natural vibration frequency is

$$f_3 = \frac{1}{2\pi}\sqrt{\frac{12(10)^6(1.57)}{10(6.43)}} = 86 \text{ cps}$$

Example 2—Branched Multiple-Rotor System

The main drive of a ship consists of a branched shaft-and-rotor system identical to that shown in Fig. 3. Elements A and C are low and high-pressure turbine rotors, B and D are intermediate gears, E is the final gear and F is the propeller. Rotor inertias and shaft lengths, based on a uniform shaft diameter of 10 in. and corrected for speed, are: $I_A = 7.24(10)^6$ lb-in.-sec^2, $I_B = 1.029(10)^6$ lb-in.-sec^2, $I_C = 0.47(10)^6$ lb-in.-sec^2, $I_D = 1.085(10)^6$ lb-in.-sec^2, $I_E = 0.345(10)^6$ lb-in.-sec^2, $I_F = 0.416(10)^6$ lb-in.-sec^2, $L_{AB} = 0.02$ in., $L_{BE} = 2.26$ in., $L_{CD} = 0.05$ in., $L_{DE} = 2.26$ in., and $L_{EF} = 166$ in. Modulus of rigidity of the shaft material $G = 12{,}000{,}000$ psi. Determine the lowest natural frequency of torsional vibration for the system.

Polar moment of inertia of the shaft cross section is $J_p = 982$ in.^{4} For the first trial calculation, assume $K = 67(10)^6$. Nodal distance $l_A = K/I_A{}^e = 67/7.24 = 9.26$ in. Also $l_C = K/I_C{}^e = 67/0.47 = 142.5$ in. The complete tabular solution is given in Table 2.1.

Since $I_F{}^e = 0$, the assumed value of K must be correct. From Equation 1, lowest natural vibration frequency of the system is

$$f_1 = \frac{1}{2\pi}\sqrt{\frac{12(10)^6(982)}{67(10)^6}} = 2.11 \text{ cps}$$

Table 2.1

$I/10^6$	L	$I^e/10^6$	l	$l - L$	I^e(referred)$/10^6$
First Branch					
$I_A = 7.240$		$I_A{}^e = 7.24$	$l_A = 9.26$		
	$L_{AB} = 0.02$			$l_A - L_{AB} = 9.24$	$I_{AB}{}^e = 7.25$
$I_B = 1.029$		$I_B{}^e = 8.28$	$l_B = 8.09$		
	$L_{BE} = 2.26$			$l_B - L_{BE} = 5.83$	$I_{BE}{}^e = 11.50$
Second Branch					
$I_C = 0.470$		$I_C{}^e = 0.47$	$l_C = 142.5$		
	$L_{CD} = 0.05$			$l_C - L_{CD} = 142.5$	$I_{CD}{}^e = 0.47$
$I_D = 1.085$		$I_D{}^e = 1.55$	$l_D = 43.1$		
	$L_{DE} = 2.26$			$l_D - L_{DE} = 40.8$	$I_{DE}{}^e = 1.64$
Main Shaft					
$I_E = 0.345$		$I_E{}^e = 13.48$	$l_E = 5.00$		
	$L_{EF} = 166$			$l_E - L_{EF} = -161$	$I_{EF}{}^e = -0.416$
$I_F = 0.416$		$I_F{}^e = 0$			

Example 3—Equivalent 2-Rotor System

In the branched system of Example 2, lengths of the branches are small as compared to the length of the propeller shaft. It is possible, therefore, to lump the five moments of inertia, I_A, I_B, I_C, I_D and I_E, together and to replace the branched system with an equivalent 2-rotor system, Fig. 3.1. In this equivalent system, $I_X = 10.17(10)^6$ lb-in.-sec^2, $I_Y = 0.416(10)^6$ lb-in.-sec^2, and $L_{XY} = 166$ in. Nodal distance l_X for this system can be determined from

$$l_X = \frac{I_Y L_{XY}}{I_X + I_Y} = \frac{0.416(10)^6(166)}{(10.17 + 0.416)(10)^6} = 6.52 \text{ in.}$$

Thus, for the equivalent 2-rotor system, frequency factor $K = I_X l_X = 10.17(10)^6(6.52) = 66.4(10)^6$ which is about 1 per cent lower than the value for the branched system (Example 2).

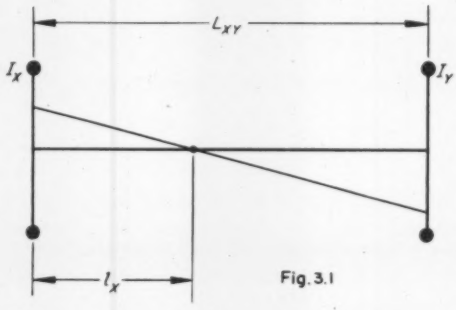

Fig. 3.1

A new method for

Measuring *High-Temperature* Stresses

with strain-sensitive
ceramic-base coatings

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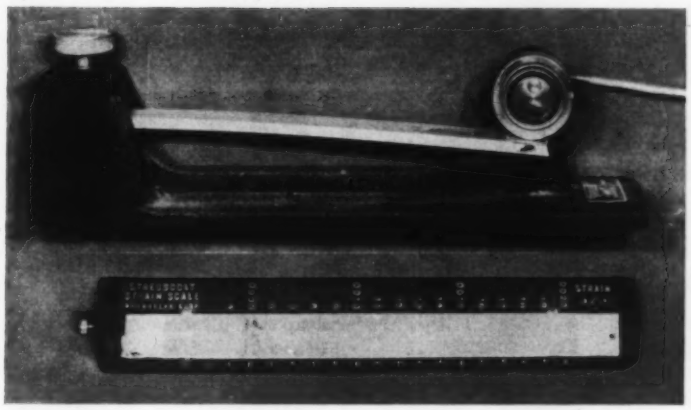


Fig. 1—*Top*—Calibration bar loaded as cantilever beam. Because coefficient of expansion data for certain metals may not be available, calibration bars are of the same material as the structure tested. *Bottom*—Strain scale and test strip. The scale measures the strain threshold of sensitivity at which the resin-base coating begins to crack

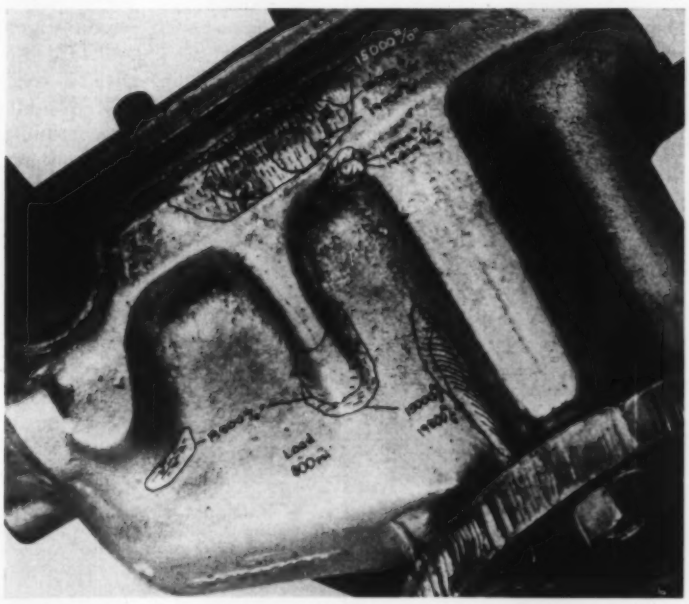


Fig. 2—Operating stresses on a cast housing caused by internal hydraulic pressure. Cracks in the resin-base coating at the fillets have been high-lighted for clarity

CALIBRATED ceramic - base coatings for experimental stress analysis yield accurate stress measurements in a temperature range from −50 to 600 F. Sensitivity varies from 200 to 1800 microinches depending upon the coefficient of expansion of the steel on which the coating is applied. Changes in temperature and humidity and presence of oil do not affect test results appreciably. If loads are applied slowly, the brittle coating gives results comparable to those obtained from impact loading. Dynamic tests may be conducted in areas where abrasion by air or dust prevents use of resin-base materials. Tests may now be conducted out-of-doors for indefinite lengths of time with the newer porcelain enamel coatings.

Coating Calibration: Early resin-base coatings are sprayed on the structure to be tested and then air dried for a period of 3 to 24 hr. Calibration bars, sprayed at the same time as the test structure, are loaded as cantilever beams in a

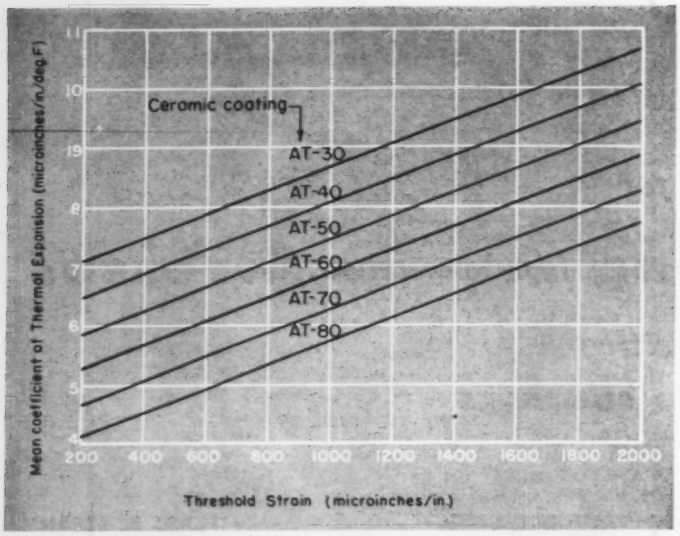


Fig. 3—Threshold sensitivity of various ceramic-base coatings. Mean coefficient of thermal expansion is shown for temperature range of 80 to 600 F

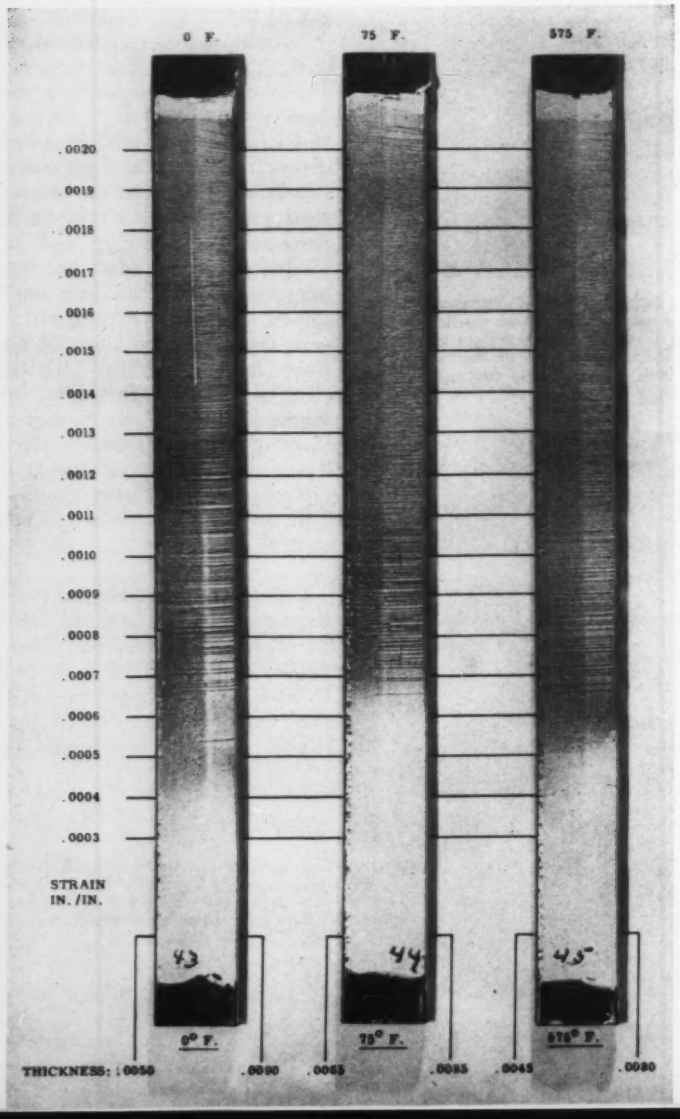


Fig. 4—Variation in strain sensitivity with coating thickness. These variations can be used as a guide to the accuracy which can be expected of strain values obtained with ceramic coatings

loading fixture, Fig. 1. These bars are then placed in a strain scale to establish threshold strain sensitivity at which the coating begins to crack. Comparison of the crack pattern with those on the part under test gives quantitative strain measurements. Multiplication of threshold strain by tension modulus of elasticity of the material being tested yields an apparent stress value for the crack pattern. Typical results obtained with resin-base coatings are shown in Fig. 2. However, use of these resin-base coatings is limited to a rather narrow temperature range from 0 to 100 F at 0 to 100 per cent humidity, and a specific coating can accommodate only a very small temperature variation. Oil attacks these coatings, and creep reduces their sensitivity considerably under long-time loading conditions.

Success of ceramic coatings depends on a controlled difference between the coefficient of expansion of the coating and that of the base metal. If the coefficient of expansion of the coating is greater than that of the base metal, residual tension will be "locked" in the coating when it cools from the firing temperature. This develops a coating which cracks at low strain levels. If, on the other hand, the coefficient of expansion of the coating is less than that of the base metal, residual compression will be locked in the coating which then requires higher strain levels to initiate crack patterns.

A selection chart for choosing a coating for use with specific materials is shown in Fig. 3. Carbon steels, for example, have a coefficient of expansion from 7 to 8 microinches/in./F, straight chromium steels from 5½ to 6½, and the austenitic chromium-nickel steels from 9 to 10. This coefficient of thermal expansion is a mean value for the range of 80 to 600 F. Since data on coefficient of expansion for a particular steel may be difficult to obtain, a calibration bar is usual-

ly made from the same material as the test structure, and the strain sensitivity of the coating is determined from it.

Structure Preparation: Part surfaces to be coated should first be degreased and then roughened by a mild sand blast. The selected ceramic is sprayed onto the part and allowed to air dry for at least 15 min to allow some of the thinner to evaporate. Small parts are then fired for about 15 min in an oxidizing furnace at 950 to 1100 F. After firing, the part is removed from the furnace and allowed to air cool prior to testing. Results of testing a number of bars of 1090 steel with a particular coating at various temperatures are shown in Fig. 4. Strain sensitivity does not vary appreciably with changes in temperature to 600 F as shown in Fig. 5.

Cracks in the ceramic coating are found by spraying the coating with electrostatically charged particles. Particles are discharged at and adhere to cracks in the coating. These charged particles may also be applied prior to the test to be thrown off at points where cracks form.

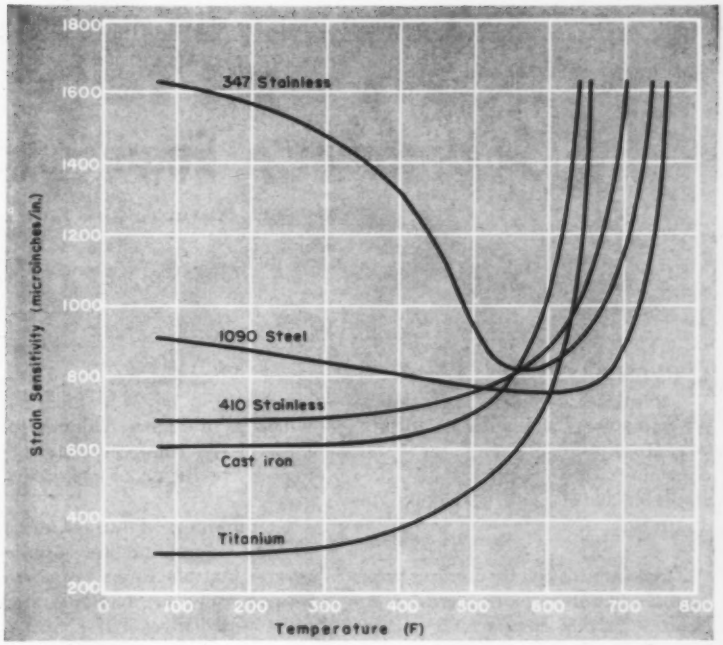


Fig. 5—Effect of temperature on strain sensitivity of ceramic coatings

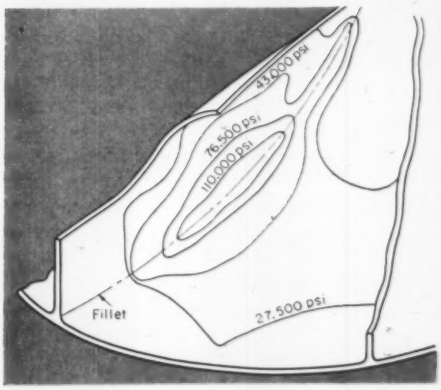
Coating Application: Progressive crack patterns which occurred during spin tests of a gas turbine are shown in Fig. 6. The threshold strain sensitivity of the coating was 0.0009 in. per in. Assuming a modulus of elasticity of 30 million psi for steel, the threshold of apparent stress amounts to approximately 27,000 psi. Over-all stress distribution at 50,000 rpm is shown in Fig. 7.

A 4130 steel ring having a varying wall thickness from ½ to 1½ in. was tested with ceramic coatings of different threshold strain sensitivities. The ring was refrigerated at −65 F, heated rapidly to 350 F, and subjected to an impact load. Although eight months elapsed between the time of coating the ring and running the test, successful results were obtained.

From a paper entitled "Ceramic Coatings for Experimental Stress Analysis," presented at the Symposium on Elevated Temperature Strain Gages, December, 1957.

Fig. 6—Ceramic coating application involving gas turbine rotor at 25,000 rpm. Calculated threshold of stress is approximately 27,000 psi

Fig. 7—Over-all stress distribution in gas turbine rotor at 50,000 rpm determined from ceramic coating crack pattern



Uncommon Engineering Metals

By J. P. DENNY and L. F. KENDALL Jr., General Electric Co., Schenectady, N. Y.

SEVEN metals which may offer solutions to particular design problems are: Zirconium, hafnium, vanadium, columbium, tantalum, chromium, and rhenium. All are available in at least developmental quantities.

Zirconium: The outstanding property of zirconium is its corrosion resistance. It is comparable to titanium, tantalum, Stellite, the Hastelloys, and stainless steels. For some applications, zirconium is markedly better than any of these since it is resistant to both alkaline and acidic media. It has a lower density than stainless steel, but its thermal conductivity is about the same. Although the metal is moderately strong at room temperature, strength drops rather sharply at elevated temperatures.

Among devices which have been fabricated from zirconium are heat exchangers, valves, reaction vessels, agitators, and fan blades. Potential uses include electrolytic capacitors, rectifiers, and surgical devices.

Hafnium: In general, hafnium has properties similar to zirconium. This metal also has a higher melting point than zirconium, a much higher allotropic transition temperature, and nearly twice the density. Like zirconium, hafnium is unusually resistant to many corrosive fluids but is attacked by air and other gases at elevated temperatures.

Vanadium: In the hot-rolled and annealed condition, vanadium has a pronounced yield point, and its stress-strain curve resembles that of mild steel. Its density is 0.22 lb per cu in. and its modulus of elasticity is 18 to 19 $\times$ 10^6 psi. This combination of properties suggests possible future structural applications. Electrical resistivity at room temperature is 24.8 microhm-cm, which is a higher value than for most of the common metals. It is a poor conductor of magnetic flux.

Columbium: Powders and granules of columbium are supplied by several manufacturers, and wrought forms are also available. Sheet, strip, foil, wire, rods, and other shapes can be produced by powder metallurgy or arc-melting followed by cold-working.

Columbium does not work-harden rapidly and can be cold-rolled and formed readily. It is resistant to acid corrosion, although it is inferior to tantalum in this respect. The material has strength at 2200 F comparable to that of pure molybdenum, and has a density of 0.31 lb per cu in. in comparison to other refractory metals. It is a superconductor at temperatures below 8 K, and has the highest superconducting temperature of any known element with the exception of technicium.

Tantalum: This metal has exceptional resistance to corrosion by acids such as hydrochloric, nitric, sulfuric, and phosphoric. It oxidizes readily above 572 F, and protective coatings are required for elevated-temperature service in air. Tantalum can be annealed by heating in vacuum to above 2327 F.

Tantalum applications include heat exchangers, condensers, and coils. Tantalum electrodes are used in electrolytic rectifiers, and sheet is being used in capacitors.

Chromium: Oxidation resistance of chromium is good at elevated temperatures but inferior to nickel-chromium alloys. The metal is hot-worked by extrusion, forging, and swaging. Powder-metallurgy processes also may be used for consolidation.

Potentialities of chromium and chromium-base alloys for structural application are not regarded as good at the present time. It is considered likely that initial application of chromium-base alloys will include bearings, tool materials, and dies.

Rhenium: This metal is difficult to fabricate but special techniques can produce bars, strip, foil, and wire from sintered powder. Because of hot shortness, rhenium cannot be hot-worked and, instead, must be cold-worked with frequent anneals at about 3100 F. Cold-working rhenium to 30 per cent area reduction triples the hardness of the metal.

The outstanding property of rhenium is its combination of high melting point, low vapor pressure, ductility at room temperatures, and very high strength. Unusual physical properties are density, melting point, and vapor pressure. Its modulus of elasticity is exceeded only by osmium and iridium. Tensile strength at room temperature is higher than that of tungsten, and rhenium is appreciably ductile at room temperature in contrast to tungsten. At elevated temperatures, ductility of rhenium is poor, although in tensile and creep-rupture properties it is superior to tantalum, columbium, and tungsten to at least 2500 F.

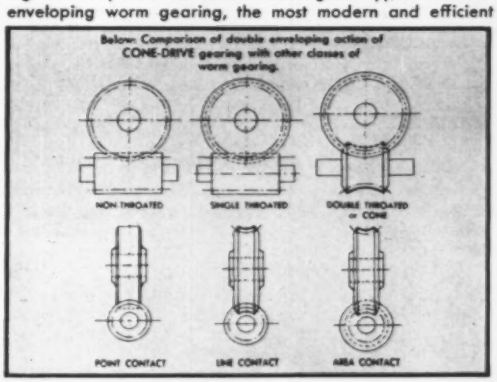
Principal potential applications of rhenium include electron tubes, and contacts in electrical relays and switches. Rhenium as a contact metal has been put to limited use in magnetos for engines.

From a paper entitled "Uncommon Engineering Metals," presented at the Design Engineering Conference in Chicago, Ill., April, 1958.

TEAR OUT AND MAIL IN FOR COMPLETE DATA

How to get the most out of Worm Gearing

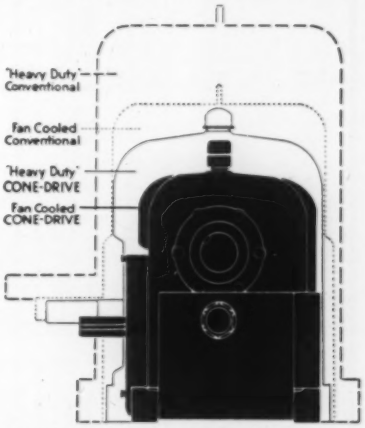
If a right-angle drive is needed in your product and you require maximum capacity for your dollar, then the Cone-Drive double-enveloping type will give it to you. The sketch below shows the apparent advantages of Cone-Drive gearing as compared to other worm gear types. Double-enveloping worm gearing, the most modern and efficient


Below: Comparison of double enveloping action of CONE-DRIVE gearing with other classes of worm gearing.
NON THROATED
SINGLE THROATED
DOUBLE THROATED or CONE
POINT CONTACT
LINE CONTACT
AREA CONTACT

form, has straight-sided teeth in both worm and gear. Both elements of Cone-Drive are throated and envelop each other, providing a multiple tooth area contact. This means greater load-carrying capacity than is possible with any other type of worm gearing.

Double-enveloping worm gearing is available from Cone-Drive Gears in complete lines of gearsets, speed reducers and gearmotors. Gearsets are stocked in center distances from 2" thru 24", capable of handling loads from fractional to over 1600 horsepower. A complete line of mountings for gearsets is also stocked.

Speed reducers and gearmotors with Cone-Drive double-enveloping worm gearing are unusually compact and powerful drives that handle shock loads with ease. Yet, they provide power transmission smoother than that of hydraulic systems. Another advantage, unique to double-enveloping worm gearing, is their ability to regenerate themselves when wear occurs. Both worm and gear tend to reproduce the correct form in the other when wear occurs.



Double-enveloping worm gearing with its "wrap-around design" requires shorter center distances than cylindrical worm gearing to handle the same loads. As a result, Cone-Drive speed reducers have smaller housings with corresponding savings in weight and space. Bulky gear trains can often be replaced with a single Cone-Drive speed reducer or gearset.

DOUBLE-ENVELOPING WORM GEARSETS
DOUBLE-ENVELOPING WORM GEAR SPEED REDUCERS
DOUBLE REDUCTION WORM GEAR SPEED REDUCERS
DOUBLE-ENVELOPING RIGHT ANGLE GEARMOTORS

Please send me information on following:

☐ Gearsets ☐ Gearmotors ☐ Speed Reducers

Name_____

Title_____

Company_____

Street_____

City_____ State_____

CONE-DRIVE GEARS
DIVISION MICHIGAN TOOL COMPANY
7171 E. McNichols Road • Detroit 12, Michigan
Telephone: TWinbrook 1-3111

TEAR OUT AND MAIL IN FOR COMPLETE DATA

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Helpful Literature
for Design Executives

For copies of any literature listed, circle Item Number on Yellow Card — page 19

Fluid Flow Products

Engineered fan and drive assemblies, vibration dampers and isolators, turbochargers, superchargers, pumps, seals, and impellers are among products briefly covered in brochure. Manufacturing and engineering facilities are also described. 12 pages. Schwitzer Corp., Indianapolis, Ind. J

Circle 601 on Page 19

Pneumatic Check Valve

A 2½ in. pneumatic check valve designed to check rapidly reversing high temperature, high pressure surges is subject of descriptive form F-8532. 2 pages. Barber-Colman Co., Aircraft Controls Div., Rockford, Ill. K

Circle 602 on Page 19

Bucket Elevators

Featured in Brochure 5784 on line of Rex industrial bucket elevators are simplified selection data to facilitate choice of proper equipment. Catalog stresses balanced design of elevators in which all components are mated or matched for rated capacity. Elevators range in capacities from 5 to 495 tons per hour. 36 pages. Chain Belt Co., Dept. Pr, Milwaukee 1, Wis. K

Circle 603 on Page 19

Industrial Rolls

Industrial roll buying guide No. 180 details information about engineering, construction, and application of all types of wood, rubber, metal, and plastic rolls. Rodney Hunt Machine Co., Industrial Roll Div., 50 Maple St., Orange, Mass. B

Circle 604 on Page 19

Potentiometers

Series of six data sheets offer details of potentiometer line. Design features, specifications, dimensional drawings, and performance graphs are included for each model. 2 pages each. Topp Mfg. Co., 5255 W. 102nd St., Los Angeles 45, Calif. L

Circle 605 on Page 19

Selective Speed Drives

Selective speed drives, subject of illustrated Bulletin 11-1, are motor speed controls using alternating current. Their ratings, advantages, and applications are covered. 8 pages. Century Electric Co., 18th & Pine Streets, St. Louis 3, Mo. I

Circle 606 on Page 19

Top Plate Conveyor Chain

Dura-Weld conveyor chain features top plate projection-welded to chain link plates. It is detachable at any link, and is interchangeable with present roller chains of the same general type. Available brochure describes Dura-Weld chain. Diamond Chain Co., 402 Kentucky Ave., Indianapolis 7, Ind. J

Circle 607 on Page 19

Jacks, Plugs, Switches

Illustrations, prices, schematics, and dimensional drawings of an extensive line of electronic adaptors, connectors, jacks, jack panels, jack covers, audio mixers, plugs, and switches are found in Catalog S-58. Wide variety of models is offered. 28 pages. Switchcraft Inc., 5555 N. Elston Ave., Chicago 30, Ill. I

Circle 608 on Page 19

Variable Transformers

Standard 50/60 cycle Power Stat variable transformers are described in detail in illustrated Manual-Catalog P258G. Engineering data, outline drawings, connections, ratings, and charts are included on standard and some special-use types. Selection data is simplified. 100 pages. Superior Electric Co., Bristol, Conn. B

Circle 609 on Page 19

Reproduction Materials

"Short Cuts and Savings with Kodagraph Reproduction Materials" is title of booklet on materials for protecting original drawings, simplifying print distribution, restoring old and worn drawings, reproducing blueprints, speeding drawing revision, combining standard designs, and saving time with photo-drawings. 12 pages. Eastman Kodak Co., Rochester 4, N. Y. N

Circle 610 on Page 19

Temperature Controls

Facilities for design and manufacture of temperature controls, detectors, and indicators are described in brochure, "The Fenwal Spectrum." Research, engineering, production, quality control, products, and affiliated companies are detailed. Seventy photos are included. 30 pages. Fenwal, Inc., Pleasant St., Ashland, Mass. B

Circle 611 on Page 19

Solenoid Valves

Ratings, flow diagrams, engineering data, illustrations, and prices for stock line of Asco solenoid valves are contained in Stock List 505. Two, three, and four-way types in various sizes are covered. 8 pages. Automatic Switch Co., Hanover Rd., Florham Park, N. J. D

Circle 612 on Page 19

Beryllium Facts

Industrial hygiene aspects of beryllium metal, oxide, alloys, and other beryllium products are discussed in booklet "Plain Talk on Beryllium." It states that some forms of the metal, when improperly handled, constitute a hazard, but that this hazard need not be viewed with alarm. 12 pages. Beryllium Corp., Box 1462, Reading, Pa. E

Circle 613 on Page 19

Motor Couplings

Low cost MC geared flexible motor couplings for transmitting electric motor power to pumps, generators, speed reducers, and other equipment are described in illustrated Bulletin 2875. Sealed units for shafts up to 1⅞ in. accommodate angular and/or parallel misalignment. 4 pages. Link-Belt Co., Prudential Plaza, Chicago 1, Ill. J

Circle 614 on Page 19

Circuit Breakers

Fundamentals of selective short-circuit protection for motor circuits are covered in Bulletin 5040-A. It reviews features and applications of Type ETI molded-case circuit breakers—instantaneous magnetic-trip devices. 8 pages. I-T-E Circuit Breaker Co., Small Air Circuit Breaker Div., Philadelphia 30, Pa. C

Circle 615 on Page 19

Wire Mesh Heaters

Available forms of wire mesh heating elements are described and illustrated in Bulletin 6010. Ratings, applications, and physical characteristics are given, and terminals are described. 4 pages. Electrofilm, Inc., Box 106, North Hollywood, Calif. L

Circle 616 on Page 19

Wing & Cap Nuts

Various types of wing and cap nuts in varied configurations are subject of series of specification sheets. Thread data, finishes, tolerances, applications, and sizes for the die cast zinc alloy fasteners are given. Gries Reproducer Corp., 125 Beechwood Ave., New Rochelle, N. Y. D

Circle 617 on Page 19

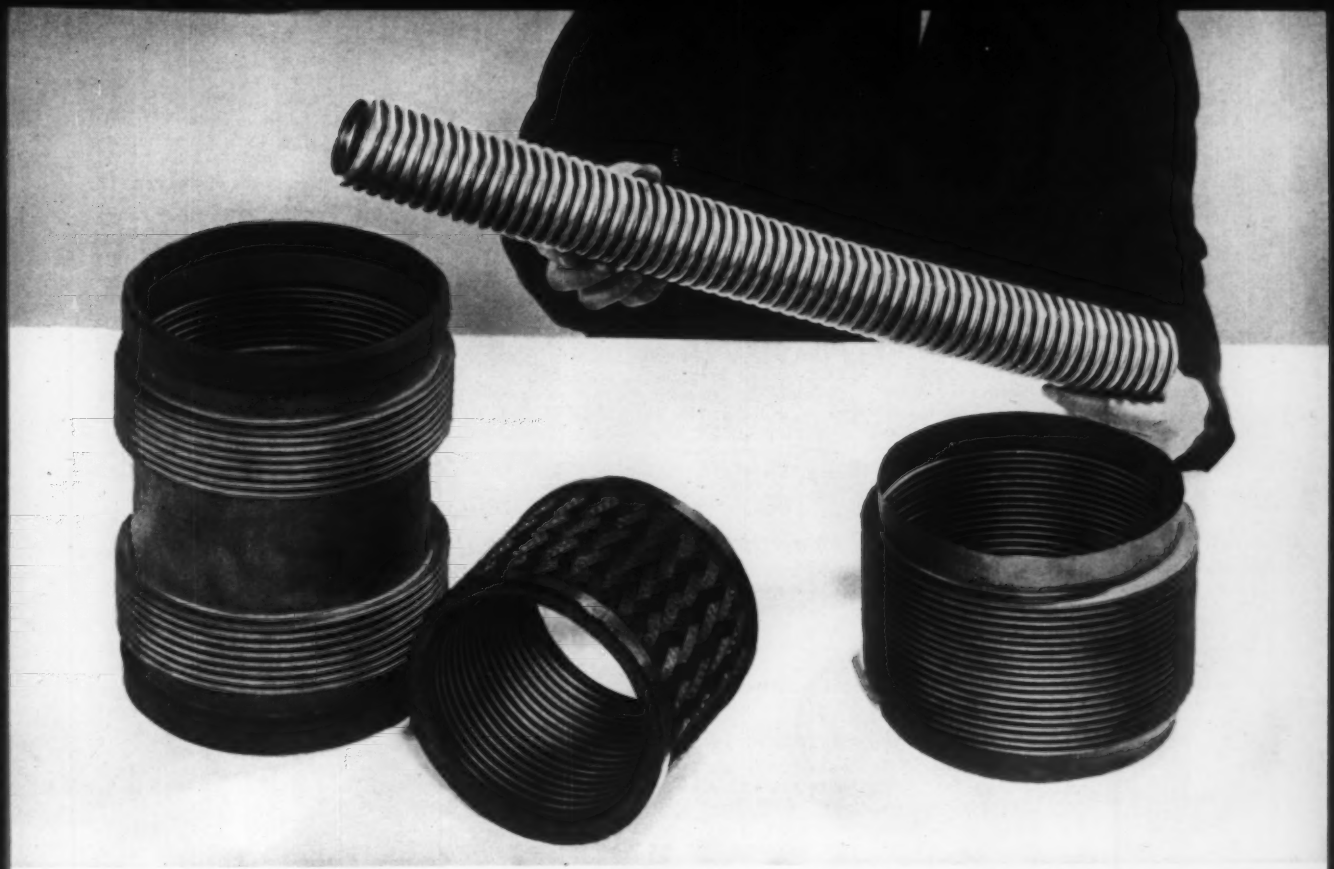
Flange Collars

Data Sheet 8-435 describes the 3LC flange collar for use with Huckbolt fasteners. Design advantages are covered and dimensions, collar material, and finish are tabulated. 1 page. Huck Mfg. Co., 2480 Bellevue Ave., Detroit 7, Mich. H

Circle 618 on Page 19

Ceramic Magnet Pulleys

Series 410 and 710 Index V permanent magnet pulleys for tramp iron separation in belt conveyor systems are described in



FLEXIBLE CONNECTORS, in a variety of sizes, constructions, materials, are designed to meet many working conditions. Our sales representatives in cooperation with our engineering design service will be glad to be of assistance.

BIG space-age problems get BIG flexible metal tube answers

Large-diameter flexible metal connectors in stainless steel and other alloys—to handle expansion and contraction, wide range of temperatures, corrosive fluids, high pressures, and vibration.

Jet engines, modern chemical plants, rockets, atomic energy plants have created a new technology that calls for new products. The American Metal Hose Division of The American Brass Company is constantly working with design engineers on special flexible connector assemblies to meet new problems.

Equipped to work in stainless steel, Monel, and aluminum as well as in other alloy steels and copper alloys, these Anaconda specialists welcome the opportunity to help you get the flexible metal hose you need to meet your problems of expansion and contraction, movement, vibration, corrosion, pressures, and temperatures.

FREE TECHNICAL SERVICE. For engineering assistance on special products—or for a free copy of our General Catalog showing the full line of standard American Flexible Hose and Tubing products—write: The American Metal Hose Division, The American Brass Company, Waterbury 20, Connecticut.

58168

WHEREVER CONNECTORS MUST MOVE

AMERICAN
FLEXIBLE METAL HOSE AND TUBING
an
ANACONDA®
product

Circle 465 on Page 19

THE AMERICAN BRASS COMPANY
American Metal Hose Division, Waterbury 20, Conn. MD

Please send me your free, 60-page General Catalog containing basic information on all types of metal hose and tubing, fittings, etc.

NAME & TITLE .....

ADDRESS .....

COMPANY .....

CITY, ZONE, STATE .....
(PLEASE PRINT OR TYPE)

illustrated folder P-1021. Efficiency achieved by radial pole design is explained. Selection data are included. 4 pages. Indiana Steel Products Co., Stearns Magnetic Products Div., 635 S. 28th St., Milwaukee 46, Wis. J

Circle 619 on Page 19

Galvanometers

Principle of operation, construction features, characteristics, special applications, and selection data for galvanometers are contents of illustrated Bulletin 1528A on Series 7-300 galvanometers. Series of graphs show operational characteristics. 12 pages. Consolidated Electrodynamics Corp., 300 N. Sierra Madre Villa, Pasadena, Calif. L

Circle 620 on Page 19

Air Valves

Four-way valves and manifolds; two and three-way line valves; manual valves and manifolds; and pilot and special valves are described and illustrated in the four sections of this general catalog on air control valves. Application and operational data, specifications, dimensional drawings, and parts lists are included. 108 pages. Numatics, Inc., Highland, Mich. H

Circle 621 on Page 19

Stainless Fabrication

Examples of products produced from 24-gage to ½-in. stainless steels, Monel, nickel, Inconel, Hastelloy, and titanium are shown in the brochure "Craftsmen in Stainless Steel Since 1929." A wide variety of products and the facilities for making them are covered. 20 pages. Alloy Products Corp., 1045 Perkins Ave., Waukesha, Wis. K

Circle 622 on Page 19

Blind Fastener

A blind fastener with threads that grip any material from 0 to ⅜ in. thick is the Jack Nut described in illustrated folder. How it is used, its specifications, and advantages are presented. 4 pages. Molly Corp., Reading, Pa. E

Circle 623 on Page 19

Tracing Papers

Weilco transparentized tracing papers which take pencil and ink, erase without ghosts, never become yellow or brittle, and minimize rips and tears are described in folder which includes samples. 4 pages. J. H. Weil Co., 1332 Cherry St., Philadelphia 7, Pa. E

Circle 624 on Page 19

Meter Mountings

Sensitive instruments can be protected against shock and vibration by the bonded rubber meter mountings described in Bulletin 601. Illustrations show typical applications. Specifications include an application cross-reference table of various meter models. 4 pages. Lord Mfg. Co., 1635 W. 12th St., Erie, Pa. F

Circle 625 on Page 19

Motors & Drives

Color-coded sections in electric power drive Catalog 258 simplify drive selection. It contains prices, modifications, and dimensions on squirrel cage ac motors, Slo-Sped and right angle gearmotors, Multi-Mount speed reducers, and Speed-Trol and right angle variable speed drives. Units with from 0.27 to 200 hp and 0.17 to 4660 rpm are covered. 64 pages. Sterling Electric Motors, Inc., 5401 Telegraph Rd., Los Angeles 22, Calif. L

Circle 626 on Page 19

Bushings & Hubs

Grip-Master steel split-tapered bushings and weld-on hubs for accurate shaft installation of sprockets, pulleys, sheaves, gears, and couplings are covered in illustrated Bulletin 201. Specifications of various models are presented. 4 pages. Cullman Wheel Co., 1344 Altgeld St., Chicago 14, Ill. J

Circle 627 on Page 19

Anticorrosion Coating

Niphos process which gives any mild steel corrosion resistance approaching that of stainless steel is subject of technical bulletin. Its advantages, abrasion resistance, ductility, and weldability are covered. Tube Reducing Corp., Box 959, Passaic, N. J. D

Circle 628 on Page 19

Hydraulic Cylinders

Technical data, specifications, detailed drawings, and cutaway photos of Series h 2000 to 3000-psi hydraulic cylinders are contained in Bulletin 102. Also included are mounting data for the 1½ to 12-in. bore units. Mo-Bar Hydraulic Sales, Inc., Crystal Lake, Ill. J

Circle 629 on Page 19

Proportioning Pump

Technical details and specifications of the McCannameter, "the meter that pumps," are found in illustrated Bulletin 302. The proportioning pump is available in diaphragm or bellows construction with maximum capacities from 6 cc per minute to 6 gph. Maximum discharge pressure is 2500 psi. 8 pages. Hills-McCanna Co., 4597 W. Touhy Ave., Chicago 30, Ill. I

Circle 630 on Page 19

Resistors

Engineering Bulletin R-26 describes Series 200 precision wire-wound resistors. Specifications for the ultra-miniaturized, 0.01-per cent accurate, hermetically encapsulated units are given. 2 pages. Consolidated Resistance Co. of America, 44 Prospect St., Yonkers, N. Y. D

Circle 631 on Page 19

Potentiometers

Brochure summarizes key information on all types and models of screw-actuated potentiometers. A specification summary table also gives price data. Bourns Laboratories, Inc., Box 2112, Riverside, Calif. L

Circle 632 on Page 19

Four-Way Valves

Information detailed on Denison four-way valves in Bulletin VD-7-A includes JIC symbols and installation data. Covered are ¾-in. pilot-operated and solenoid-controlled valves for 3000-psi systems. 8 pages. American Brake Shoe Co., Denison Engineering Div., Columbus 16, Ohio. G

Circle 633 on Page 19

Materials Technology

"Advanced Materials Technology" is title of new publications dealing with materials which meet severe or unusual conditions in processing or operation, such as extreme heat, abrasive action, or corrosion. Those interested can be placed on mailing list. Carborundum Co., Niagara Falls, N. Y. N

Circle 634 on Page 19

V-Belt

Folder S-5192 describes HY-T V-belt which features 3-T synthetic fiber cord in its construction. This triple-tempered cord has surplus stretch removed, and allows belt to operate under tension without excessive stretching. 4 pages. Goodyear Industrial Products, Akron 16, Ohio. F

Circle 635 on Page 19

Metallic Lubricant

General lubrication recommendations for the use of Molub-Alloy metallic lubricant are given in series of Lubrication Recommendation Sheets. These recommendations can extend lube cycles up to 500 per cent. Imperial Oil & Grease Co., 6505 Wilshire Blvd., Los Angeles 48, Calif. L

Circle 636 on Page 19

Clamps, Couplings & Joints

File folder contains ten Marman brochures on clamps, straps, V-band and channel band couplings, and Live and Conoseal joints for aircraft, industrial, marine, farm, and railroad uses. Aeroquip Corp., Marman Div., Jackson, Mich. H

Circle 637 on Page 19

Way Protectors

Several installations of Gortite neoprene-base accordion way protectors are shown in Bulletin GW-100. Protectors on a horizontal milling and boring machine open to 90 ft and close to 24 in. 4 pages. A & A Mfg. Co., 712 S. 12th St., Milwaukee 4, Wis. K

Circle 638 on Page 19

Gasoline Engines

Revised bulletins HA-2 and HA-4 provide performance data and specifications on improved two-cylinder and four-cylinder Hercules air-cooled gasoline engines. 2 pages each. Hercules Motors Corp., 101 Eleventh St. S.E., Canton, Ohio. G

Circle 639 on Page 19

Plugs & Chip Detectors

Various uses of magnetic plugs and magnetic chip detectors are pointed up in file-size design reference booklet. It also contains section on self-closing valves and Dri-Seal pipe plugs. 22 pages. Lisle Corp., Magnetic Plug Div., 807 Main St., Clarinda, Iowa. I

Circle 640 on Page 19

Photoelectric Cells

Encompassing a wide range of shapes and sizes, self-generating photoelectric

Circle 466 on Page 19→

Better Tools...

BEGIN WITH SHARON QUALITY ALLOY STEELS

What's new in the way of garden tools? This tool caddy, for one thing, and Sharon metallurgists know all about it.

Sharon has been supplying carbon, stainless and special alloy steels to garden and farm implement manufacturers for more than 50 years and they know the industry and its requirements.

So, if you're in the business of farm and garden tools, isn't it just good business to become acquainted with . . .Sharon Quality Steels?

SHARONSTEEL

SHARON STEEL CORP.

SHARON, PENNSYLVANIA

P&B PROGRESS

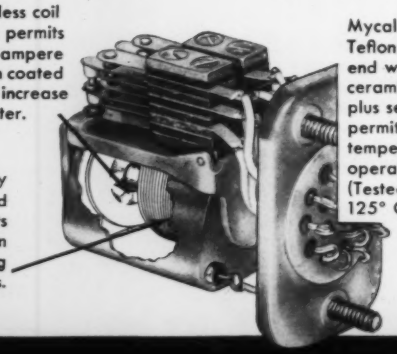
IMPROVED! SEALED COIL, TELEPHONE-TYPE RELAY.

NEW! DUAL HERMETIC SEAL INCREASES RELAY RELIABILITY AND TEMPERATURE RANGE

LOOK AT THESE GREAT NEW FEATURES

New bobbinless coil saves space, permits use of more ampere turns of Teflon coated wire with no increase in coil diameter.

Hermetically sealed coil prevents gases from contaminating contacts.



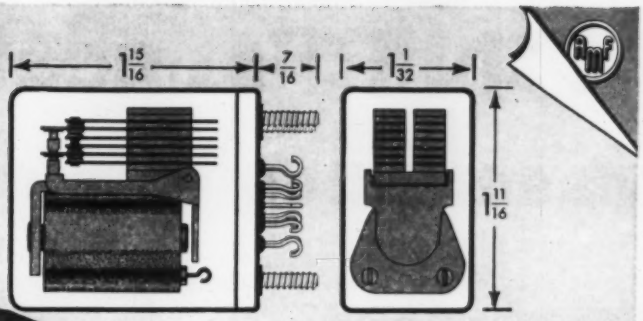
Mycalex stack, Teflon wire and end washers and ceramic pushers, plus sealed coil, permit high temperature operations. (Tested up to 125° C.)

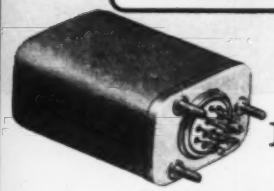
Hermetically sealing the coil of the MH "Seal-Temp" substantially increases the reliability and life of this popular telephone-type relay. Considered a major reason for relay failure, contact contamination due to outgassing of the coil has been eliminated by this sealing process.

The "Seal-Temp" has a temperature range considerably broader than ordinary relays... from −65° C to +125° C. This is achieved by constructing the stack of Mycalex, employing ceramic pushers, and by using Teflon coated wire throughout.

For applications where reliability, long life and broad temperature ranges are required, the MH "Seal-Temp" relay could well be the answer. Write, wire or call today for complete information.

POTTER & BRUMFIELD, INC., PRINCETON, INDIANA / SUBSIDIARY OF AMERICAN MACHINE & FOUNDRY COMPANY





MH "SEAL-TEMP" RELAY

GENERAL: Insulating Material: Ceramic, Mycalex and Teflon.
Insulation Resistance: 1,000 meg ohms min.
Breakdown Voltage: 500 V. RMS.
Shock: 30g's.
Vibration: 5g's 55 to 500 cps.; .032" max. excursions 5-55 cps.
Temperature Range: −65° C to +125° C.
Pull-in: Approximately 75% of nominal voltage at 25° C.
Terminals: Miniature plug in; hook end solder.
Enclosure: Short "M" Can, hermetically sealed.

CONTACTS: Arrangements: Up to 6 springs per stack. (4PDT)
Material: ⅛" Silver (others available).
Load: 5 amp. 115V. AC resistive.

COILS: Resistance: Up to 22,000 ohms.
Power: 100 mw per movable arm min.; 4 watts max. DC at 25° C. (200 mw min. to meet shock or vibration requirement at 25° C.)
Duty: Continuous.
Insulation: Teflon.
Coil Chamber: Hermetically sealed.

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONIC, ELECTRICAL AND REFRIGERATION DISTRIBUTORS

Potter & Brumfield, inc.

PRINCETON, INDIANA

SUBSIDIARY OF AMERICAN MACHINE & FOUNDRY COMPANY
Manufacturing Divisions also in Franklin, Ky. and Laconia, N.H.

Mail the coupon for complete engineering data on the new MH Series, plus new compact catalog of standard type relays. If you need answers to a specific application problem write in detail.

Potter & Brumfield, Inc., Princeton, Indiana
Attn: T. B. White, Brig. Gen. USMC (Ret.)
Special Projects Engineer

Please send me complete engineering data on the new MH Series Relay plus the new compact catalog of P&B standard relays.

Name_____

Company_____

Address_____

City_____ Zone____ State_____

Circle 467 on Page 19

cells described in Bulletin EPD 3216-1 consist of a metal base with coating of selenium and other metals. Design details and suggested uses are given. 12 pages. Vickers Inc., Electric Products Div., 1815 Locust St., St. Louis 3, Mo. I

Circle 641 on Page 19

Heat Exchanger Tube

Company line of heat exchanger tubes is pictured in folder entitled "Buying Heat Exchanger Tube?" Each of these integrally finned tubes is available in a wide range of types, alloys, and sizes. 4 pages. Calumet & Hecla, Inc., Wolverine Tube Div., 17206 Southfield Rd., Allen Park, Mich. H

Circle 642 on Page 19

Crane Controls

In addition to being a catalog of Clark dc crane control equipment, Bulletin 9100 is a manual on selection and application. It covers a basic dc hoist circuit, on through bridge and trolley motions and includes system components. 20 pages. Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio. F

Circle 643 on Page 19

Centrifugal Compressors

Engineering data and performance characteristics of centrifugal compressors, as well as guidance to writing specifications, are featured in Catalog 150. Sections include one on horizontally and vertically split compressors and on compressor fundamentals, parts, drivers, and specification. 64 pages. Clark Bros. Co., Olean, N. Y. N

Circle 644 on Page 19

Rubber Components

Bulletin 715 pictures and describes company facilities and typical products of natural, synthetic, and silicone rubber; polyurethane; and flexible vinyl. These molded and extruded parts are bonded to metal or other materials. 6 pages. Ohio Rubber Co., Willoughby 1, Ohio. F

Circle 645 on Page 19

Heating Equipment Motors

Dimensions, ratings, and sizes of fractional-hp split-phase, capacitor start, shaded-pole, and permanent-split capacitor motors for domestic heating equipment are covered in Bulletin GEA-6718. 8 pages. General Electric Co., Schenectady 5, N. Y. C

Circle 646 on Page 19

Potentiometers & Motors

Engineering data relative to 1, 3, and 10-turn Micropot potentiometers; direct reading 10, 100, and 1000-turn Microdials; concentric scale Microdials; and instrument motors is featured in Catalog BED-A90. George W. Borg Corp., Borg Equipment Div., 120 S. Main St., Janesville, Wis. K

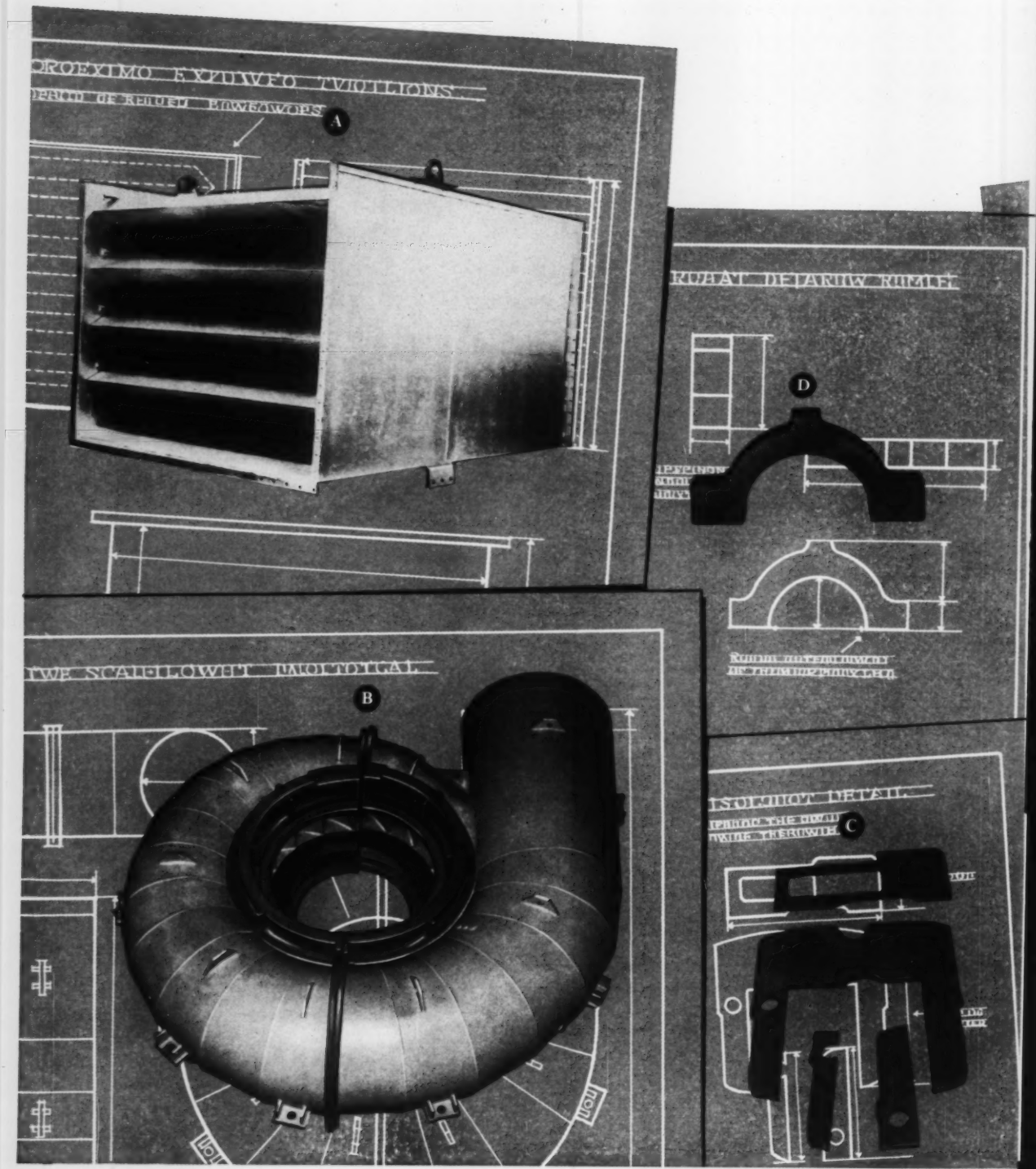
Circle 647 on Page 19

Lighted Switches

Wide selection of lighted pushbutton switches, lamps, and buttons shown in Data Sheet 133 will give panel designers

CLAYMONT Fabricated

complete assemblies or simple



Steel Plate Products . . .

parts – made to your specifications

Our modern, production-line Fabrication Shop is fully equipped and prepared to serve you by converting the steel plate of your choice into the parts or components you need.

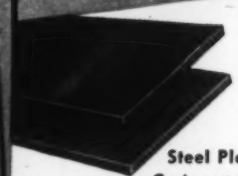
Getting exactly the right steel is no problem . . . Claymont makes its own. Every steel-production step is controlled within the company—from open hearth to finished fabrication. Top quality is assured. Your most exacting specifications are met or exceeded.

Small or large-quantity orders are handled with equal facility, and Claymont can offer quick-delivery service by water, rail or highway.

Use Claymont's complete facilities as a supplement or extension of your own. Contact our office nearest you for prompt, dependable assistance in solving your parts problems.

The products shown here are representative of the wide range of work Claymont's Fabrication Shop performs for its customers. Whether you need large, complex, fully-fabricated production weldments like a noise suppressor for turbines (A) or a scroll casing for hydroelectric installations (B)—or simple component parts like flame cut side and rear plate assemblies for fork lift trucks (C) or heavy gage steel bearing shells for marine turbines (D)—Claymont can fabricate them to your exact specifications. Claymont's 100,000 square foot facility includes a complete range of equipment for welding, pressing, shearing, flame-cutting, bending and machining.

OTHER CLAYMONT PRODUCTS



Steel Plates
Carbon • Alloy
Stainless-Clad • Nickel Plated
High Strength Low Alloy

Spun and Pressed Heads

Manhole Fittings and Covers

Large Diameter Welded Steel Pipe

CF&I

Claymont Steel Products

Products of Wickwire Spencer Steel Division • The Colorado Fuel and Iron Corporation
P.O. Box 1951 • Wilmington, Delaware

Albuquerque • Amarillo • Atlanta • Billings • Boise • Boston • Buffalo • Butte • Chicago • Denver • Detroit • El Paso
Ft. Worth • Houston • Kansas City • Lincoln • Los Angeles • New Orleans • New York • Oakland • Odessa • Oklahoma City
Philadelphia • Phoenix • Portland (Ore.) • Pueblo • Salt Lake City • San Francisco • San Leandro • Seattle • Spokane • Tulsa • Wichita
CF&I OFFICES IN CANADA: Montreal • Toronto CANADIAN REPRESENTATIVES AT: Calgary • Edmonton • Vancouver • Winnipeg

6155

Endurance RATED

PIC-600
ELECTRIC COUNTERS

Basemount
Knob reset

- 50 Million Count Life
- 7 watts power consumption—operable in plate circuit of electronic tubes.
- 1000 CPM rating—reliable to 1600 with suitable actuation.
- Quiet—no AC hum.
- Balanced armature—for reliability on airborne equipment.

Panelmount, knob reset

Panelmount, key reset

See your PIC Distributor or send for Catalog.

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Stroke Counters.
Revolution Counters
Electric Counters and Actuators.
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Automatic Batch Counters.

Production Instruments
DIVISION OF GENERAL CONTROLS CO.
8078B McCormick Blvd., Skokie, Ill.
42 Branch Offices and Representatives serving USA and Canada

Circle 469 on Page 19

HELPFUL LITERATURE

great freedom of layout. Lamp selection data are provided. 8 pages. Minneapolis-Honeywell Regulator Co., Micro Switch Div., Freeport, Ill. K

Circle 648 on Page 19

Rubber & Plastic Products

"Engineering Reference Book of Molded Extruded Die-Cut Parts" lists all types, dimensions, and durometers of grommets, bumpers, bushings, suction cups, caps, cylinder spring stock, packings, rods, rollers, sleeves, stoppers, and gaskets. 28 pages. Miller Products Co., 29 Warren St., New York 7, N. Y. D

Circle 649 on Page 19

Motor Insulation

Advantages of Thermalastic insulation, which will extend the life of large motors and generators, synchronous condensers, and frequency changers, are discussed in Booklet B-7249. 12 pages. Westinghouse Electric Corp., Box 2099, Pittsburgh 30, Pa. F

Circle 650 on Page 19

Resin Curing Chemicals

Properties, general information, typical chemical reactions, suggested uses, and other information relative to HET Anhydride and HET Anhydride Coanhydride Systems for Epoxy Resins are given in Bulletins 43 and 19, respectively. 21 and 18 pages. Hooker Electrochemical Co., Niagara Falls, N. Y. N

Circle 651 on Page 19

Subminiature Switches

Photos, drawings, operating characteristics, and electrical ratings pertinent to Unimax line of snap-acting subminiature switches is presented in Bulletin 25. Switches are shown in basic form and with a variety of actuators. 4 pages. W. L. Maxson Corp., Unimax Switch Div., Ives Rd., Wallingford, Conn. B

Circle 652 on Page 19

Fluid Pumps

Advantages of Hydroid fluid pumps are pointed up in Hupp folder. Pumps feature an elliptical tooth form which does not trap fluids. 4 pages. Hupp Aviation Co., 6633 W. 65th St., Chicago 38, Ill. J

Circle 653 on Page 19

Fractional HP Motor

Type FSE-23 1/40-hp, 5000-rpm motor described in Bulletin 1034 is designed for intermittent duty in adding machines, calculators, check protectors, check signers, and actuators. Construction and operation are covered. 4 pages. Bodine Electric Co., 2254 W. Ohio St., Chicago 12, Ill. J

Circle 654 on Page 19

Heating Controls

Condensed heating Catalog, 1957-58 Edition, briefly describes and specifies thermostats, time switches, fan limit controls, pressure and temperature controls, gas valves, pilot valves, gas heating package sets, water heater controls, safety valves, pilot burners, regulators, relays,

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18-8 TYPE 303 STAINLESS
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Manufacturers of electronic equipment have come to depend on Curtis for precision-made non-magnetic universal joints of 18-8 Type 303 stainless steel, in the sizes most frequently used in the industry. Other sizes are also readily available; also bronze joints.

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A MANUFACTURER OF UNIVERSAL JOINTS SINCE 1919

Circle 470 on Page 19

magnetic valves, and other control equipment. 66 pages. General Controls Co., 801 Allen Ave., Glendale 1, Calif. L

Circle 655 on Page 19

Small Couplings

Structural details of subminiature and midget type Oldham couplings for remote controls, servo mechanisms motion transmission, and instrumentation are given in Bulletin 5795. Price sheet 5775 supplements the bulletin. Kupfrian Mfg. Corp., 395 State St., Binghamton, N. Y. N

Circle 656 on Page 19

Flow Regulator

Engineering data on 3000-psi adjustable flow regulator available in ¼, ⅜, and ½-in. pipe sizes are given in folder. Flow rates for the three sizes are 5, 10, and 18-gpm, respectively. 2 pages. Fluid Power Accessories, Inc., Glenview, Ill. J

Circle 657 on Page 19

Flexible Tubing

All types of flexible tubing and hose, and the many types of couplings used with them, are described and illustrated in technical booklet. Use is for conveying air, water, steam, gases, granular materials, and all types of liquids. Available only on request from Pennsylvania Flexible Metallic Tubing Co., 7200 Powers Lane, Philadelphia 42, Pa. E

Precision Gears

Facilities for making fine-pitch UQ precision gears are described in illustrated Bulletin 5811. Gears range from 300 to 24 diametral pitch, from 0.0625 in. in diameter up, and are produced to AGMA or individual specifications. Request directly from Western Gear Corp., Box 182, Lynwood, Calif. L

Variable Speed Pulley

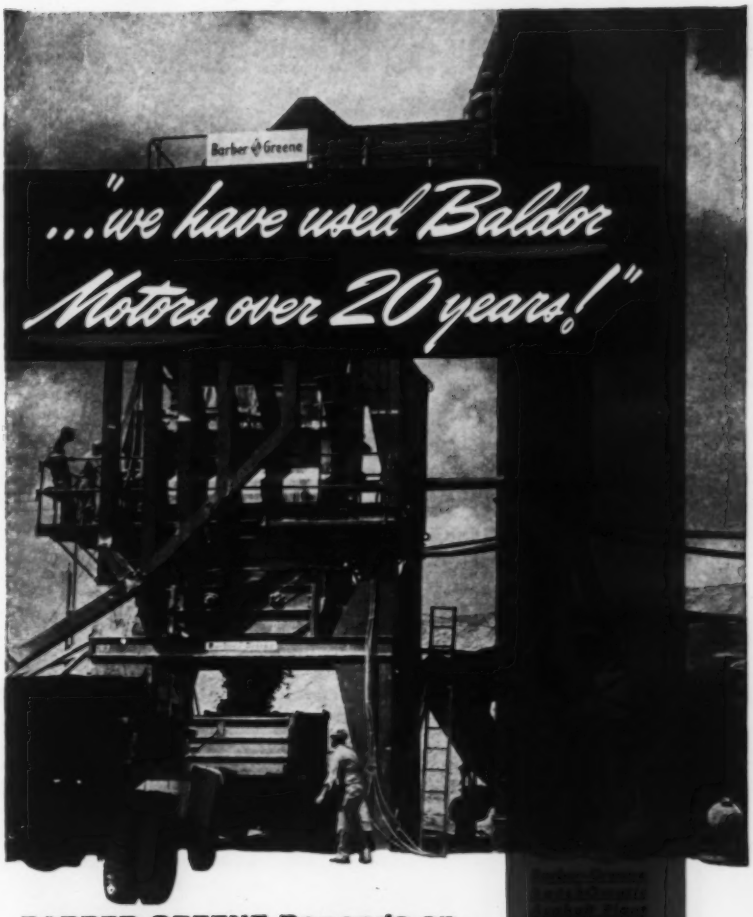
The 90 Series Vari-Speed motor pulley, for ½ to 15-hp applications, with up to 4 to 1 ratios of speed variation, is subject of Bulletin V-582. Its construction features, engineering details, and dimensional drawings are included. Request on letterhead from Reeves Pulley Co., 1225 Seventh St., Columbus, Ind. F

Thermoplastics Properties

Up-to-the-minute fabrication data on thermoplastic materials appear in easy-to-read type on a properties chart, intended for cut-out or paste-up use. Photos show typical parts fabrications. The 7 x 12-in. chart is available by requesting on company letterhead from Comco Plastics, Inc., 97-24 Albert Rd., Ozone Park 17, N. Y. D

Air Line Drafting Aids

Sets of Layout Tracers which make it easy for the draftsman to "lay in" various units of the Crown Line of filters, regulators, lubricators, and accessories are available by writing directly to this company. Eight cards in three scales are slipped under the tracing for use. Request directly from Hannifin Co., 516 S. Wolf Rd., Des Plaines, Ill. J



BARBER-GREENE Depends on Baldor Streamcooled Motors to Power Its Asphalt Batch Plants & Belt Conveyors!

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This kind of superior performance has earned Baldor an enviable reputation among many outstanding heavy equipment manufacturers.

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Circle 471 on Page 19

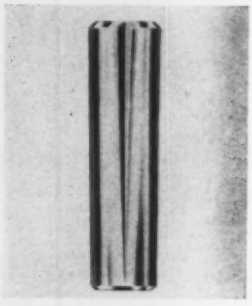
New Parts and Materials

Use Yellow Card, page 19, to obtain more information

Grooved Fasteners

provide high resistance to shear, shock, fatigue

Shear-Proof high-strength, alloy-steel, heat-treated grooved fasteners are designed for pinning, fastening, hinging, and anchoring in applications where ultimate strength and reliability are required. Providing maximum resistance to shear, shock, and fatigue, pins have applications in materials-



handling equipment, farm machinery, power - transmission units, pumps, and similar equipment. They can replace alloy dowels, bolts, key and setscrew assemblies, and hollow pins (used singly or one inside the other). Pins are driven or forced into a hole and are locked in place until deliberately driven or forced out. **Driv-Lok Sales Corp.**, 777 Park Ave., Sycamore, Ill. I

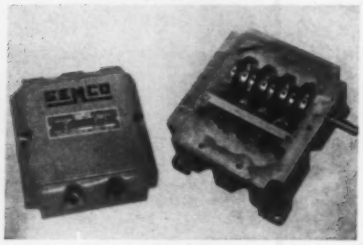
Circle 658 on Page 19

Limit Switch

rotating-cam unit has speed to 400 rpm

Rotating-cam limit switch in NEMA Type 7 enclosure is an explosionproof unit with adjustable cam-lobe assemblies. Switch has high speed rating up to 400 rpm. One type of cam can be adjusted to meet all requirements by loosening a screw and rotating cams relative to each other to desired position. Either open or closed circuits can be obtained in continuous range from 360 down to about 8 deg. Single-pole, double-throw switch contacts have 15 amp rating at 115 v and 5 amp at 440 v. Switch is also available in NEMA 1, 4, 5, 7, and 12 enclosures, two to twelve circuits, high and low speeds. Optional features include double shaft extensions and gear reductions. **Gemco Electric Co.**, 25685 W. Eight Mile Rd., Detroit 40, Mich. H

Circle 659 on Page 19

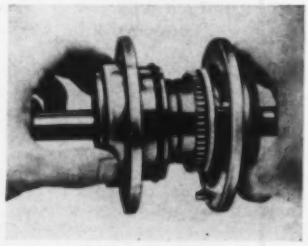


Flexible Coupling

for shaft diameters up to 1⅞ in.

Type MC geared flexible coupling is designed for use as a motor coupling to transmit electric motor power to pumps, generators, and speed reducers. It is for shaft diameters up to 1⅞ in. Externally geared hubs are mounted on shafts and joined flexibly by an internally geared sleeve. Coupling sleeve is of one-piece design, and coupling is enclosed in two-piece metal cover, sealed to prevent loss of lubricant or entry of contaminants. Spiral cam-locking fasteners, permanently assembled as part of cover halves, require only a quarter-turn for fastening or detaching. **Link-Belt Co.**, Dept. PR, Prudential Plaza, Chicago 1, Ill. J

Circle 660 on Page 19



Miniature Connectors

are for use with coaxial cable

ECC series of miniature coaxial connectors is designed for use with coaxial cable and for mounting on printed-circuit boards. Connectors are available in a 50-ohm, constant-impedance group, and 50 and 93 - ohm, nonconstant - impedance groups. Connector bodies are brass with albaloy plating, and insulation is machined Teflon. Rated voltage for the series is 500 v dc. Mounting pins are for standard 5/32-in. line spacing. Units shown

include a straight receptacle, a right-angle receptacle, a 360-deg, swivel-type receptacle, and an interchangeable mating plug. **H. H. Buggie Inc.**, Box 817, Toledo 1, Ohio. G

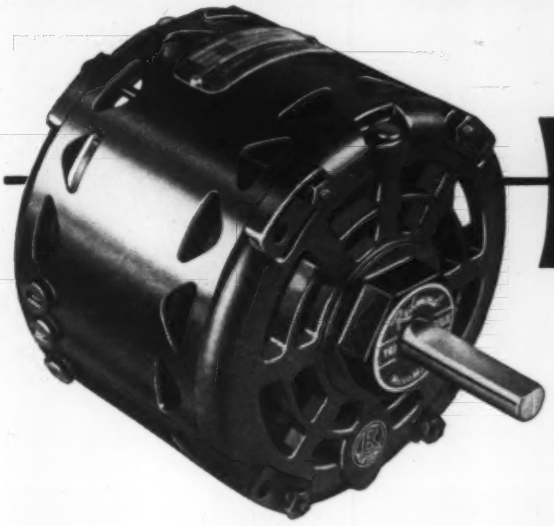
Circle 661 on Page 19

AC Generator

brushless unit is for commercial vehicles

New alternating current generator is capable of continuous output of

Reduce Costs By Using New, More Powerful Shaded Pole Motors In Your Appliances



Redmond
TYPE AY TRI-FLUX
SHADED POLE MICROMOTORS

Redmond's New Design Greatly Increases Shaded Pole Motor Application

Now you can reduce costs by using the powerful new Redmond Tri-Flux® shaded pole motor in applications that formerly required more costly general purpose motors.

Redmond's patented Tri-Flux design adds a third flux path with a "reluctance notch" in the leading pole tip making possible a larger diameter shaded pole motor that is more efficient and has higher starting and running torques than conventional shaded pole motors. It is this exclusive Redmond feature that makes your shaded pole motor powerful enough to replace the more costly types you may now be using and which may be over-motoring your product.

The basic AY shaded pole MicroMotor pictured above is available in both 4 and 6-pole designs, ranging through 1/3 horsepower in many applications. It can also be modified readily and economically to fit your exact specifications for both mechanical and fan duty requirements.

The Redmond type AY Tri-Flux shaded pole motor is a quality product yet it is still the most economical style motor available when properly applied and tailor-made to fit your requirements. Designed and developed by the Redmond Company, millions of these motors are now in operation in a multitude of air-conditioning, refrigeration, heating and ventilating applications where years of trouble-free service and whisper-quiet operation is essential. The Redmond Company has been a specialist in the design and production of shaded pole and fraction horsepower motors for more than a generation and have produced well over 70,000,000 motors during this period and is considered a leader in its field. Redmond motors are constructed with UL and CSA approved materials and methods and you may be assured that production motors will maintain the same high quality-precise specifications found in hand made test samples.

Redmond sales engineers are skilled technicians whose primary function is applying a motor to your production. Call us today to help you with your cost reducing program.

HAVE YOU INVESTIGATED THE LATEST DEVELOPMENTS IN MOTORS?

Redmond engineers want to help you adapt these motors to your specific needs. Contact us at Owosso, Michigan, and we will have the Redmond sales engineer in your district call you at once.

The Standard of Dependability

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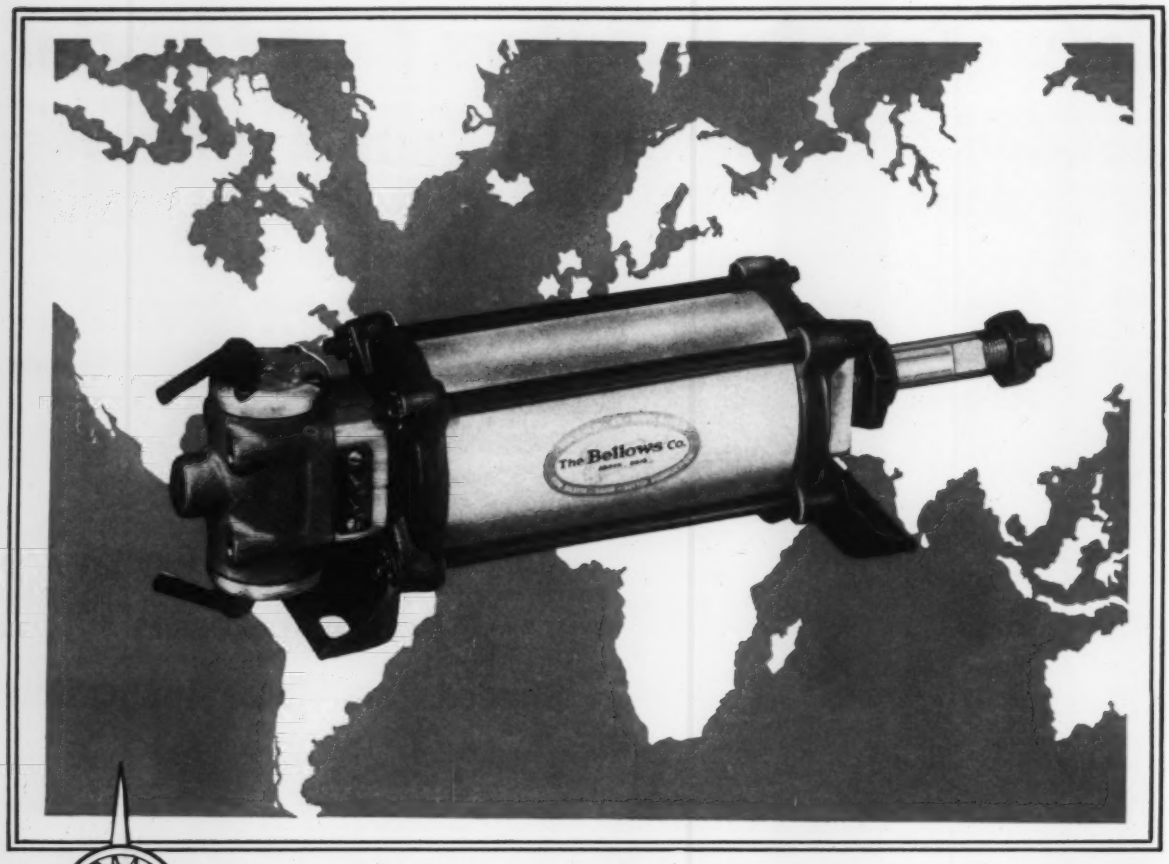
COMPANY, INC.
OWOSSO, MICHIGAN

ADVERTISED IN The Saturday Evening POST

THE BIG NAME IN SMALL MOTORS

Circle 472 on Page 19



SERVICE AVAILABILITY IS ANOTHER MAJOR REASON WHY OEM DESIGNERS SPECIFY BELLOWS AIR MOTORS

In your products, as in ours, service to customers is an important selling tool. When you specify Bellows Air Motors and other Bellows pneumatic devices and controls as components in your machines—you know, wherever the machine will be shipped, there will be a Bellows Field Engineer nearby.

Over 150 full time, fully trained Bellows Field Engineers, in every important industrial area in the United States and Canada, in Great Britain, in Europe, and Australia are available to give quick, efficient and friendly help if it's needed. And seven manufacturing and assembly plants in the States, in Canada, in Great Britain and Europe safeguard your customers from "down time" due to "parts" delays.

Add to "service availability" the design and cost advantages this unique air cylinder with the built-in valve offers you: compactness, speed, precision-control and low cost—and it's easy to see why the Bellows Air Motor ranks first with design engineers.

This booklet tells the story
"The Place of the Bellows Air Motor in Original Equipment Design" tells in 14 quick-reading pages how the Bellows Air Motor can fit into your program. Free on request. Address Dept. MD-558, The Bellows Co., Akron 9, Ohio.

The Bellows Co.

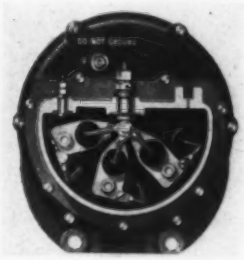
DIVISION INTERNATIONAL BASIC ECONOMY CORPORATION

AKRON 9, OHIO

1029-B

Circle 473 on Page 19

215 amp at cruising speed and 125 amp at engine idle. Available for commercial vehicles, it is a totally enclosed, brushless unit with compact, built-in silicon rectifiers, and is controlled by a transistor regu-



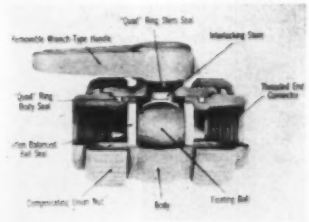
lator. Entire generator-rectifier assembly is cooled by a continuous flow of engine oil which eliminates need for forced-air cooling. Unit is completely sealed against dust, dirt, and engine cleaning solutions. Need for frequent servicing is eliminated, since there are no brushes, slip rings, or air filters, and a continuous flow of oil lubricates the bearings. Transistor regulator has no moving parts, eliminating the need for periodic adjustments. **Delco-Remy Div., General Motors Corp.**, Anderson, Ind. J

Circle 662 on Page 19

Ball Valve

polyvinyl-chloride unit is self-lubricating

Lightweight polyvinyl-chloride ball valve provides easy take-up to compensate for wear. The self-lubricating unit has straight-through, full-open, round port design which permits full flow without turbulence or directional change. Union nuts at each end of valve provide easy positioning of valve in line as well as easy disassembly for repair. Valve is available in either threaded or socket ends for installation with solvent cement. The quick-opening unit has no metal parts, will not rust or corrode. Working pressures



Ruthman Gusher Coolant Pumps are Better

PRECISION
BALANCE
with Heavy-Duty
ONE PIECE SHAFT

CUTS VIBRATION

REDUCES WEAR

INSURES LONGER... TROUBLE-FREE LIFE

PROLONGS BEARING LIFE

THE INSIDE STORY

The shaft and rotating assembly of all Gusher Coolant Pumps is electronically balanced, precision built to reduce vibration to an absolute minimum. You get reduced wear, a longer . . . trouble-free life for your Gusher Pumps.

Gusher Coolant Pumps also give you split-second coolant flow from the moment the machine is turned on. There is no priming needed.

Maintenance effort is at a minimum too. Heavy-duty pre-lubricated ball bearings require no further attention. There is no packing needed—no seals requiring replacement. Specify Gusher Pumps on your machines. Write today for catalog and price list.

ON GUSHER COOLANT PUMPS

THE Ruthman MACHINERY CO.

• COOLANT PUMPS
• CIRCULATORS • AGITATORS
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1811 Reading Road Cincinnati, Ohio

Circle 474 on Page 19

Experience**—the added alloy in **A-L Stainless, Electrical and Tool Steels

384 pages of practical data from Allegheny Ludlum

Here's the newest addition to A-L's technical library. It incorporates the knowledge gained by being the leading producer of stainless steel ever since the industry was born, and the experience gained by working with all of the leading stainless steel fabricators.

"Stainless Steel Fabrication" is a case-bound, 384-page handbook for your *working* library. It contains the latest, detailed information on: CUTTING, JOINING, COLD FORMING, HOT FORMING, MACHINING, HEAT TREATING, SURFACE TREATING.

With 308 photographs and drawings and 121 tables, this new book suggests to old timers new ways to make operations more efficient. For newer men it's a practical textbook on all operations from working mill forms to finished parts.

If you would like to receive a free, personal copy of the 384-page handbook "Stainless Steel Fabrication," contact your A-L sales engineer. Or write on your company letterhead: *Allegheny Ludlum Steel Corporation, Oliver Bldg., Pittsburgh 22, Pa. Address: Dept. MD-5.*

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EVERY FORM OF STAINLESS . . . EVERY HELP IN USING IT

for ½ to 1½-in. sizes are 140 psi at 100 F and 70 psi at 130 F. Pressure recommendations for 2 and 3-in. sizes are 100 psi at 100 F and 50 psi at 130 F. **B. F. Goodrich Industrial Products Co.**, Marietta, Ohio. F

Circle 663 on Page 19

Power Supplies

for any output between 1 and 25 v dc

TPC-5 transistorized power supplies have rated output current of 350 ma, and regulation over entire input voltage and output current ranges is 1 per cent. Supplies can be furnished for any output between 1 and 25 v dc. The 120-v ac input is reduced through a transformer, rectified in a bridge circuit and filtered. Portion of output voltage is compared to a Zener diode reference

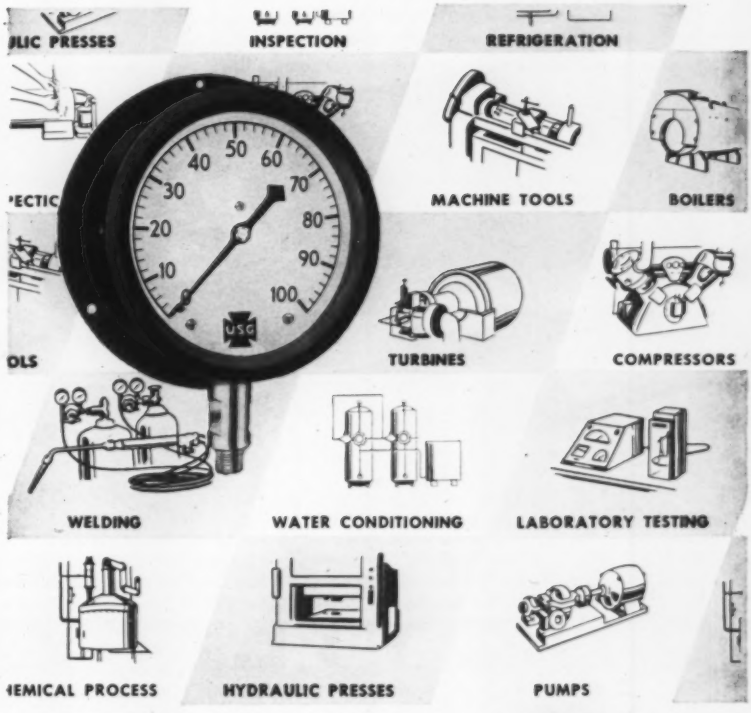
voltage, amplified in a transistor circuit, and applied to input to maintain constant output voltage. Aluminum case contains output terminal connections, switch, pilot light, and 0.25-v adjustment control on blue-anodized front panel. **Southwestern Industrial Electronics Co.**, 2831 Post Oak Rd., Houston 19, Tex. I

Circle 664 on Page 19

Push-On Nut

fastens product identifications rapidly

New push-on Speed Nut provides rapid, secure fastening for name plates, emblems, medallions, and other forms of product identification. It accommodates two 3/32-in. studs with center-to-center dimensions ranging from ¼ to ⅝ in. Fastener can be used to secure individual name-plate letters, and to fasten any 3/32-in. diam single-stud applications which are on the same unit. Nut is pressed by hand



industry buys more USG® gauges than any other make

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- Practically all industrial gauge requirements can be met by USG.
- For high sustained accuracy . . . for long, trouble-free service under severe temperature and atmospheres . . . there's the Supergauge and Solfrunt Series.
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- Buy USG gauges . . . pressure and temperature pilots, recorders and controllers . . . transmitters and thermometers . . . and be assured of guaranteed satisfaction in quality, performance and dependability.

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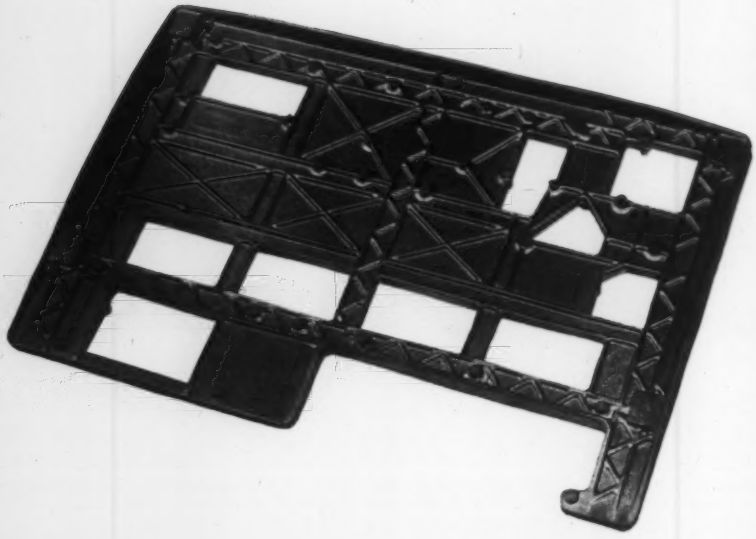
MORE THAN 50,000 TYPES OF GAUGES • SUPERGAUGES • SOLID FRONT GAUGES • RECEIVER GAUGES • TEST GAUGES • RECORDERS • CONTROLLERS • TRANSMITTERS • PSYCHROMETERS • AVIATION INSTRUMENTS

Circle 476 on Page 19



DUCTILITY

A CASE IN POINT—This ninety-six pound casting was made for the National Cash Register Co. of Nodulite®, Hamilton Foundry's ductile iron. The casting forms the base for the new Post-Tronic Accounting Machine. It measures 37½" by 23½" with sections varying from ¼" to 1½". Ductile iron was chosen for this part because of its ductility, dimensional stability, rigidity, and machinability.

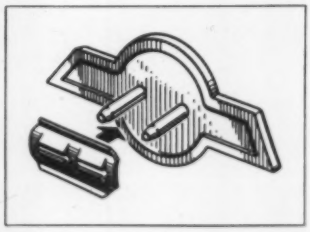
Ductile iron has most of the engineering advantages of steel yet it can be designed with the same flexibility and cast with the same procedures used for gray iron. It has high strength: up to 120,000 psi minimum tensile strength in standard grades. It is tough: Charpy impact strengths up to 115 ft.-lbs. in standard grades. It is ductile: elongation is possible up to 25% after short time annealing. And it is wear resistant: spheroidal graphite particles provide for self-lubrication. Hamilton Foundry regularly casts 60-45-10, 80-60-03, 100-70-03, and 120-90-02 grades of ductile iron as well as high alloy Ductile Ni-Resist.

When new and unusual design problems arise in the selection of metal and the casting of parts, you will find that the skill and integrity of your foundry is your best insurance that specifications—and delivery schedules —will be met.

GRAY IRON • ALLOYED IRON • MEEHANITE® • DUCTILE (NODULAR) IRON • NI-RESIST • DUCTILE NI-RESIST • NI-HARD

HAMILTON FOUNDRY

The Hamilton Foundry & Machine Co., 1551 Lincoln Ave., Hamilton, Ohio • TW 5-7491



over studs and holds name-plate or emblem firmly in a vibration-proof grip. **Tinnerman Products Inc.**, Box 6688, Cleveland, Ohio. F

Circle 665 on Page 19

Plastic Laminate

for use in copper-clad laminates

Designated GEC-500, new glass-base, epoxy-resin laminate is used in making copper-clad laminates for printed circuits. It is furnished either plain or with copper cladding on one or both sides. Material is available with copper bonded to base laminate with or without adhesive. Sheets up to ⅛ in. thick, plain or copper-clad, can be punched. Laminate combines low moisture absorption with excellent chemical and insulation resistance, low dielectric loss, and high mechanical strength. It retains electrical properties after exposure to high humidity. Base material is furnished in sheets approximately 37 x 49 in., in thicknesses from 0.010 to 1½ in., and in rods from ⅛ to 1½ in. diam. Copper-clad grades are furnished in sheets approximately 36 x 48 in., in thicknesses from 0.015 to 1 in. **Taylor Fibre Co.**, Norristown, Pa. E

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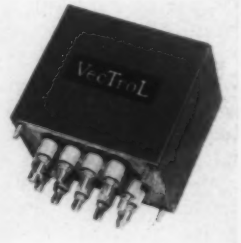
Thyratron Grid Control

for feedback circuits

New thyratron grid-control unit provides proportional control of 60-cycle, single-phase, half or full-wave



Knee high to a grasshopper

but Fenwal's New Miniature,

Here are acute temperature sensitivity, instant response, and the strength to withstand the most demanding conditions — all in *one unit only knee high to a grasshopper!*

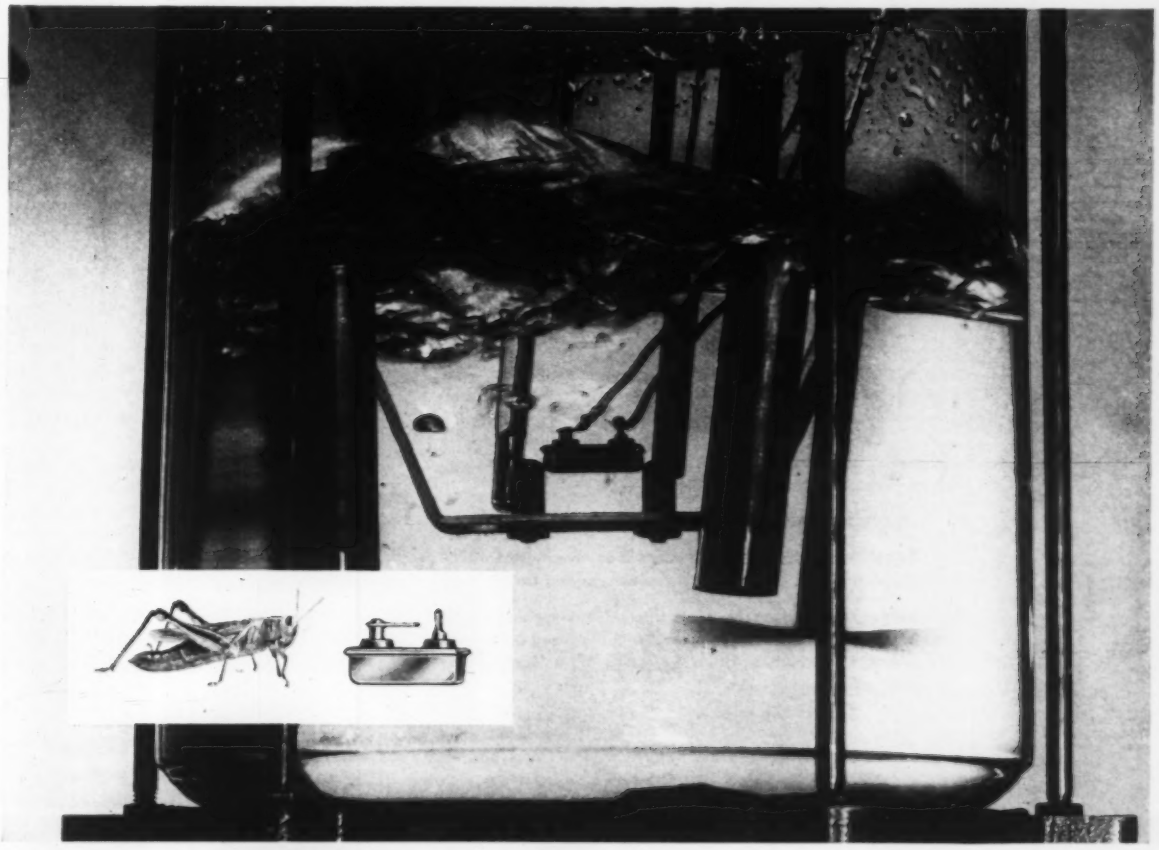
It's hermetically sealed, yet field adjustable. Maintains control characteristics even with vibrations of 500 cps with 10G acceleration — *it's rugged!*

You get wide range and sensitivity, too. The new THERMOSWITCH unit controls temperatures from −20° to +200°F within 1°. Thin wall corrosion-resistant, drawn stainless steel case insures instant response to temperature changes — *you get precision control.*

You'll want to find out more about this tiny, tough, sensitive control. For more information on the new miniature hermetically sealed THERMOSWITCH unit, and other Fenwal miniaturized controls, write for our catalog or a sales engineer. Fenwal Incorporated, 195 Pleasant Street, Ashland, Massachusetts.

Hermetically Sealed THERMOSWITCH® Unit is Strong as an Ox

New Fenwal miniature THERMOSWITCH unit being agitated in liquid bath while maintaining temperature of liquid at 140°F ±1°. THERMOSWITCH unit weighs less than ½ oz., can withstand 10G acceleration at 500 cps vibration. Current capacity is 2.5 amps, 115 VAC, 2.0 amps, 28 VDC.

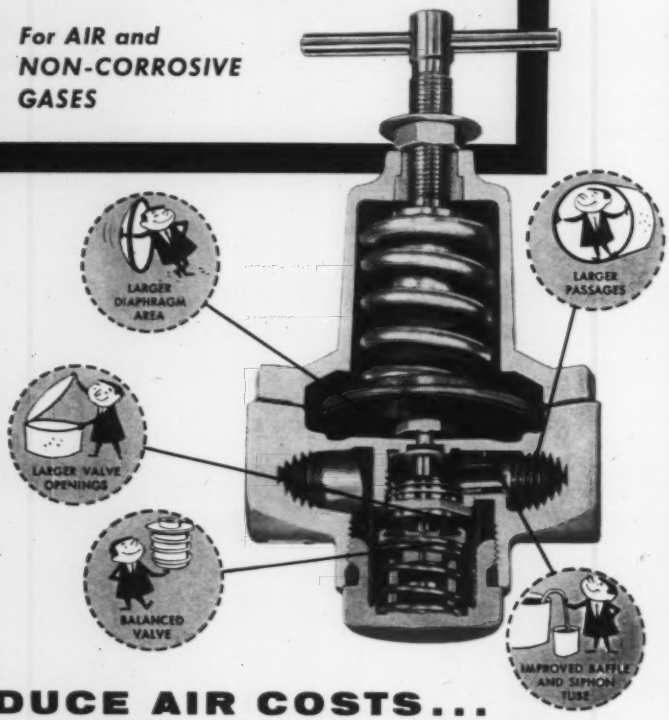


Fenwal CONTROLS TEMPERATURE . . . PRECISELY

Circle 478 on Page 19

Norgren PRESSURE REGULATORS

For AIR and NON-CORROSIVE GASES



REDUCE AIR COSTS... CUT MAINTENANCE COSTS

Most air operated equipment has one pressure at which it operates most efficiently. Above that pressure, equipment wears excessively with no significant increase in output, and compressed air is wasted. Norgren Pressure Regulators reduce line pressures to the desired working pressure, produce better equipment performance and longer life, lower maintenance and compressed air costs.

Highly Accurate over a wide operating range.

Regulated Pressure Held Constant even with widely fluctuating line pressure and rapidly varying air flow.

Large Flow Capacity—a. Balanced valve construction; b. Large effective diaphragm area; c. Improved baffle and siphon performance; d. Large passages; e. Large valve openings.

Also regulators for water, oil, other liquids and steam.

For complete information, call the Norgren Representative listed in your telephone directory—or **WRITE FOR No. 900 CATALOG.**

If it's Norgren...It's Dependable.

C. A. NORGREN CO.

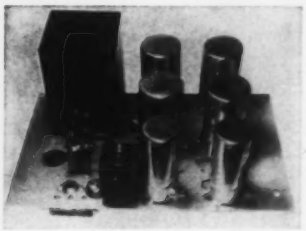
3442 SO. ELATI STREET • ENGLEWOOD, COLORADO

thyratron outputs up to several kilowatts with dc control signal of the order of 1 mw. Four isolated dc control windings provide control in accordance with several independent signals. Unit consists of sensitive phase-shifting network of static components, sealed hermetically in a can, and providing phase shift up to 300 deg. Linear proportional phase shift of 180 deg is obtainable with small dc control signal. Control requires no grid bias to ensure thyratron cutoff when control signal is removed. Unit eliminates all control tubes in feedback circuits for voltage-regulated power supplies, adjustable-speed motor drives, program speed controls, servomotors, and machine tool automation and process controls. **VecTrol Engineering Inc.**, P. O. Box 1089, Stamford, Conn. B

Circle 667 on Page 19

Power Supplies

are available in a wide range of output voltages



New transistorized, voltage-regulated power supplies are available in a wide range of output voltages to meet either commercial or military specifications. Model 7PVR14 (shown) operates from a 115-v, 60-cycle, ac power source. It provides three channel outputs: ± 2, ± 3, and ± 20 v dc at 2.5 amp. All channels are regulated to ± 0.5 per cent. **Western Gear Corp.**, P. O. Box 182, Lynwood, Calif. L

Circle 668 on Page 19

Centrifugal Blowers

miniature ac units provide up to 45 cfm free air

Four new ac miniature centrifugal blowers meet environmental requirements of MIL - M - 7969A (ASG). They incorporate either a 1½ or 2-in. rotor, and deliver up to 45 cfm free air. Either a rec-

Circle 480 on Page 19→

Circle 479 on Page 19

ALLEN-BRADLEY

new

BULLETIN 350 reversing drum switch

Styled by Brooks Stevens, internationally famous industrial designer.

- *MODERN IN APPEARANCE*
- *AVAILABLE AS OILTIGHT— FOR CAVITY MOUNTING*
- *EASY TO MOUNT*
- *EASIER TO WIRE*
- *INSTANT CHANGEOVER FROM MAINTAINED TO MOMENTARY CONTACTS*

A-B QUALITY

ALLEN-BRADLEY

MOTOR CONTROL

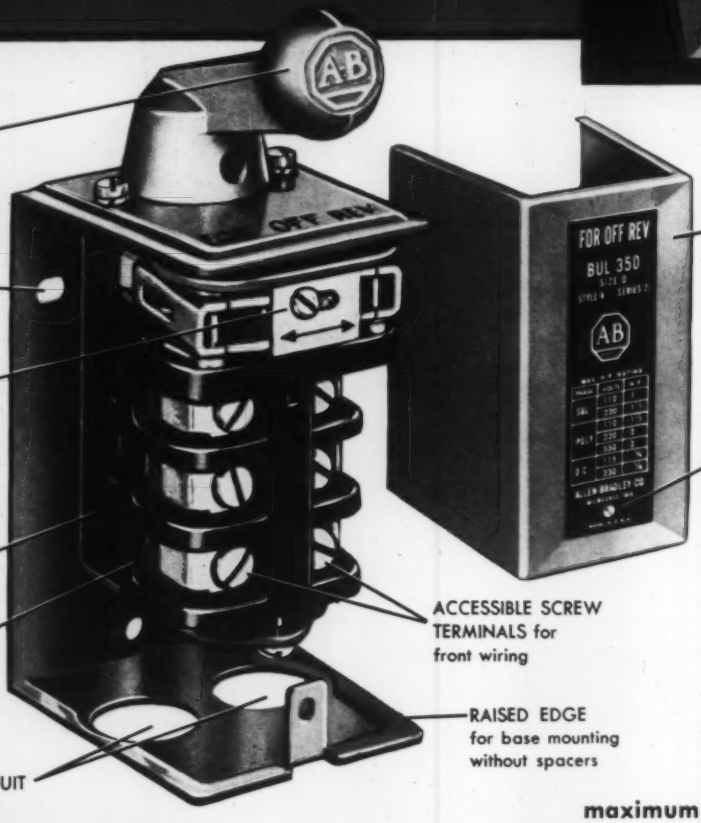
QUALITY

Allen-Bradley Co., 1316 S. Second St., Milwaukee 4, Wis.
In Canada—Allen-Bradley Canada Ltd., Galt, Ont.

6-58-MR

A new "quality" standard for small REVERSING DRUM SWITCHES

A-B QUALITY



GOOD-LOOKING AND GOOD "FEELING" DIE CAST HANDLE

EASILY ACCESSIBLE MOUNTING HOLES

MERELY LOOSEN SCREW AND SLIDE PLATE to change from momentary to maintained contacts —or vice versa

INDEPENDENT SWITCH MOUNTING prevents misalignment

HEAVY CONTACT SURFACES for long operating life

TWO CONDUIT OPENINGS

WRAP-AROUND COVER gives complete access to drum

SINGLE SCREW COVER MOUNTING —screw cannot fall out

ACCESSIBLE SCREW TERMINALS for front wiring

RAISED EDGE for base mounting without spacers

maximum rating 2 horsepower

NEW OILTIGHT COVER PLATE FOR CAVITY MOUNTING

Bulletin 350 Reversing Switch can be furnished with oiltight cover plate with rubber gasket seal for cavity mounting in a machine base.

This *all-new* Allen-Bradley reversing drum switch was designed to keep pace with the mechanical beauty designed into so many of the modern machine tools.

The Bulletin 350 reversing switch is equivalent to a three-pole, double throw switch . . . and can be used with d-c motors; or single phase, two phase, or three phase a-c motors.

Investigate the Bulletin 350 . . . the *new leader* of its class . . . in appearance, ease of installation, and operating life. An Allen-Bradley *quality* switch . . . in every sense of the word. Send for descriptive bulletin.

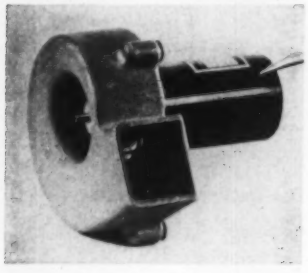
ALLEN-BRADLEY

MOTOR CONTROL

QUALITY

Allen-Bradley Co., 1316 S. Second St., Milwaukee 4, Wis.
In Canada—Allen-Bradley Canada Ltd., Galt, Ont.

6-58-MR



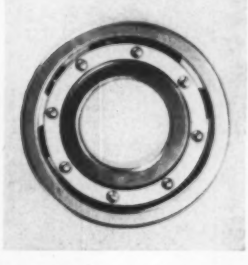
tangular or round outlet is furnished for attaching ductwork and clockwise or counterclockwise aluminum scrolls are available. Motors can be designed for frequencies between 50 and 1000 cycles with voltages up to 200 v, single or three phase. Weight of each unit is from 16 to 19 oz, depending on rotor size. **Globe Industries Inc.**, 1784 Stanley Ave., Dayton 4, Ohio. G

Circle 669 on Page 19

Ball Bearings

for operation in temperatures to 900 F

New antifriction ball bearings are deep-groove radial units, available in four sizes, 200, 202, 204, and 206. They are suitable for operation in ambient temperatures to 900 F. Both inner and outer races are M-2 high-speed steel, and balls



are M-10 high-speed steel. Bearings are manufactured to ABEC 3 and 5 accuracy, and operate at speeds up to 40,000 rpm without lubrication. **Industrial Tectonics Inc.**, 3686 Jackson Rd., Ann Arbor, Mich. H

Circle 670 on Page 19

O-Ring Tube Fitting

for vacuum, air, and hydraulic systems

New O-ring tube fitting is available in connectors, unions, elbows, tees, crosses, and bulkhead connec-

STEEL *from Wheelock, Lovejoy* BULLETIN

W-L CHICAGO Now in an ideal position to supply HY-TEN "M" Temper in large forged flats up to 6 x 22", rounds to 18" and squares to 17½". Also "B" No. 3-X in large forged flats to 6 x 13", rounds to 18" and squares to 16". Alloy forgings a specialty.

W-L DETROIT The new, larger warehouse and office here have greatly speeded up delivery on our orders and services in this area. Have a good stock of A-8620 on hand as well as all HY-TEN grades.

W-L CLEVELAND The rolls for this Vaughn Four-Roll Continuous Pointer are fabricated from HY-TEN "M" Temper, nickel-chromium-molybdenum oil hardening steel. This Pointer, largest of its type in the world, can point rods ranging from ½" to 1¼" dia. HY-TEN "M" was selected by the machine manufacturer because it can be quenched and tempered to high hardness levels while retaining considerably greater toughness than would be possible with most other steels.

W-L CINCINNATI Another new and larger warehouse recently opened here. Same-day service on all sizes, shapes and grades of HY-TEN, plus our usual help on metallurgical problems.

W-L HILLSIDE, N. J. This W-L warehouse has an excellent stock of HY-TEN "B" No. 3-X in rounds, flats and squares. Same-day delivery is promised. Many of the larger sizes of forged rounds are rough turned.

W-L CAMBRIDGE HY-TEN "B" No. 2 is still a great favorite in New England for parts requiring medium duty and high quality at a reasonable price. Our research and development assure better HY-TEN specials — "the standard alloy steels of tomorrow."

W-L BUFFALO New HY-TEN "B" No. 3X-40 now available here in rounds ½" to 8¼" and hexagons 1¼" to 2¾", heat treated to 300 Brinell. Machines as easily as heat-treated 4140 leaded, but less expensive. Suitable for flame or induction hardening — tough and shock resistant.

Write our Cambridge office today for your *free* Wheelock, Lovejoy Data Sheets. They'll give you complete technical information on grades, applications, physical properties, tests, heat treating, etc.

WHEELOCK, LOVEJOY & COMPANY, INC.
133 Sidney Street, Cambridge 39, Mass.

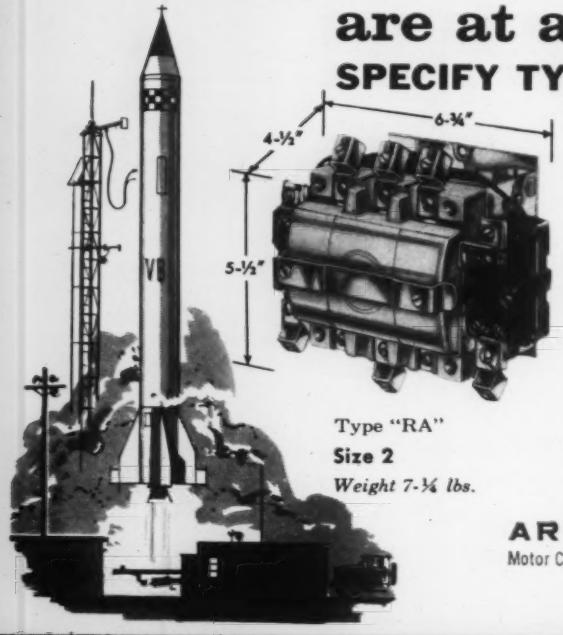
AMERICAN STEEL WAREHOUSE ASS'N

AGENTS: Southern Engineering Company, Charlotte, N. C.; Sanderson-Newbould, Ltd., Montreal & Toronto

Circle 481 on Page 19

Whenever SPACE and WEIGHT are at a Premium...

SPECIFY TYPE "RA" MOTOR CONTROLS



Type "RA"
Size 2
Weight 7-¼ lbs.

Launching, guidance, tracking and service equipment for rockets or guided missles *MUST* pack the greatest possible performance capacity into the smallest possible envelope. That's why Arrow-Hart Type "RA" Starters and Contactors have been selected for so many rocket and missile projects . . . and so many other applications where space and weight savings are all-important. Far smaller and lighter than conventional types, Arrow-Hart "RA" Controls use advanced design with greatly improved mechanical efficiency to achieve superior performance and dependability. The modern Right Angle operating mechanism insures positive operation and provides increased resistance to unfavorable atmospheric conditions.

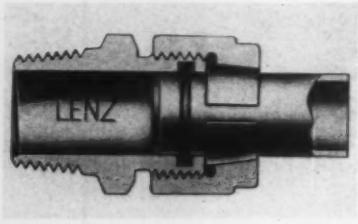
For "RA" Data Section, write now to The Arrow-Hart & Hegeman Electric Company, Dept. MD, 103 Hawthorn Street, Hartford 6, Connecticut.

ARROW – HART OF HARTFORD
Motor Controls • Wiring Devices • Appliance Switches • Enclosed Switches

Circle 482 on Page 19

ARROW AH HART

NEW PARTS AND MATERIALS



tions in tube sizes from ⅛ to 2 in. OD. Used on vacuum, air, and hydraulic systems, fitting is available in cadmium-plated steel, black phosphate finish, or stainless steel. Fitting seals by means of a standard O-ring. No exact tube length is necessary, and there is no metal-to-metal seal. **Lenz Co.**, Box 1044, Dayton 1, Ohio. G

Circle 671 on Page 19

Iron-Based Alloy

has high ratio of strength to weight

J-1300 alloy is a precipitation-hardening, iron-based alloy, especially effective in temperatures of 1300 to 1350 F. Possessing excellent strength-to-weight properties, it is supplied in forgings and bar stocks, and is applicable for turbine wheels, rings, shafts, compressor wheels, and blades, and as a bolt and fastener material. Minimum guaranteed tensile strength at 1200 F is 135,000 psi. Metal maintains high residual strength after long exposure to stress and high temperatures, and is easily fabricated. **Metallurgical Products Dept., General Electric Co.**, 11177 Eight Mile Rd., Detroit, Mich. H

Circle 672 on Page 19

Phosphor Bronze Strip

has high strength, hardness, and ductility

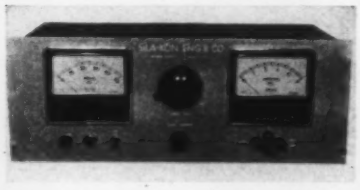
New metal, designated 200-Plus bronze, is spring-temper phosphor bronze with ductility increased by 200 per cent or more. Available in Grades A, C, and D, the metal provides greater formability and part uniformity than regular spring-temper bronze, but possesses equal strength and hardness. Metal meets all requirements of standard phosphor bronze specifications. **Rolling Mill Div., Miller Co.**, 99 Center St., Meriden, Conn. B

Circle 673 on Page 19

DC Power Supply

transistorized unit is rack or bench mounted

Model 550 variable dc power supply, operating from 115 v ac, utilizes transistor circuitry throughout. Supply incorporates overload protection that can be preset with a calibrated panel control for protection of the load. Another feature provides for remote sensing of voltage at the load. Electrical characteristics include: 3 to 45 v output, continuously variable, 0 to 5 amp; output impedance, 0.01 ohms;



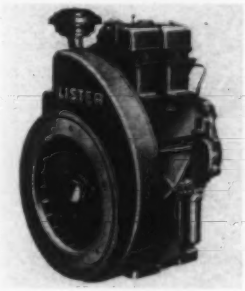
ripple, less than 8 mv. The rack or bench-mounted unit measures 19 x 7 x 7 in. **Sila-Kon Engineering Co.**, P. O. Box 282, El Monte, Calif. L

Circle 674 on Page 19

Diesel Engines

industrial power units have wide application

Model HA diesel engines are easily started by hand from either end of engine. No preheating or priming is necessary after initial run. Rotary pump situated below oil level supplies oil under pressure to all crankshaft bearings, gear train and valve rocker gear, and camshaft locating bearing; remaining parts are splash lubricated. Centrifugal governor, driven at higher than engine speed, maintains settled variation of revolutions within 4 per cent. The two and three-cylinder units develop 10 hp per cylinder at 1800 rpm. Engines are suitable for pumps, generators, air compressors, refrigerators, conveyors, and hoists. **Lister-Blackstone Inc.**, 42-32 21st St., Long Island City 1, N. Y. D



Circle 675 on Page 19

Brake Mechanism

for medium-duty casters

New positive-acting, adjustable brake features a formed brake shoe which contacts maximum area of tire tread in a vertical axis of caster. Actuating force is in line with braking force. Brake shoe is controlled by a cam action for either secure locking or complete release. Brake actuating cams, which are a preformed part of brake shoe, are fully hardened and designed to afford maximum motion of brake shoe.

Brake is designed for use with medium-duty 4 x 4-in. top plate casters, 4 to 6-in. diam casters with steel hub replaceable-tire wheels, and all rubber wheels, 4 to 6 in. in diam, with hard or soft tread. It is also applicable for rigid models. **Jarvis & Jarvis Inc.**, Palmer, Mass. B

Circle 676 on Page 19

Frequency Changer

for equipment drawing up to 100 va

Model FCR100 power supply is a low-impedance, portable frequency changer with wide range of output frequency, excellent waveform, and

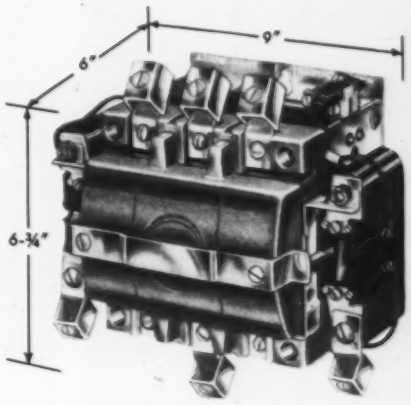
MOTOR CONTROLS

SMALLEST Magnetic Starters Available!

Arrow-Hart Type "RA" Motor Controls feature the advanced design "Right Angle" mechanism, with the magnet operating through a simple bellcrank mechanism. This provides a mechanical advantage making possible a much smaller and lighter magnet which out-performs older, direct-acting types. As a result, size and weight are reduced by almost half, while performance, operating efficiency and dependability are greatly improved. Other important "RA" design features include extra-rugged silver cadmium alloy contacts with positively guided travel for perfect alignment . . . and straight-thru wiring for simplified circuit design.

Arrow-Hart offers you the *only* complete line of smaller, lighter motor controls including: NEMA Sizes 0 through 5, in across-the-line, reversing and two-speed starters and contactors.

Write for free 16 page booklet of Motor Control Wiring Diagrams: The Arrow-Hart & Hegeman Electric Company, Dept. MD, 103 Hawthorn Street, Hartford 6, Connecticut.

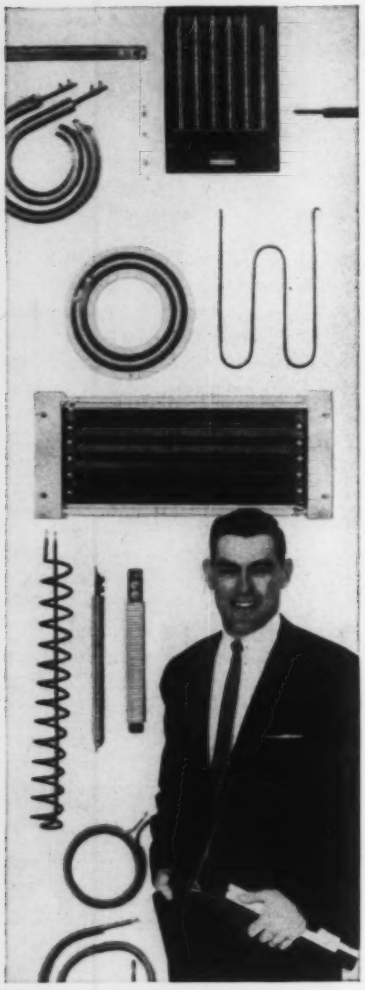


Type "RA" Starter
Size 3
Weight 15-½ lbs.

ARROW – HART OF HARTFORD
Motor Controls • Wiring Devices • Appliance Switches • Enclosed Switches

Circle 483 on Page 19

Process Air Heating?



Your Chromalox Man has the ANSWER . . .

When you need:

- **clean, moisture-free heat**
- **precisely controlled temperatures**
- **additional heat to supplement existing equipment**
- **safe, explosion-proof heat**

For finish baking, heat-treating ovens, annealing ovens, core and armature drying ovens . . . hundreds of similar applications. Operating temperatures to 1000°F. maintained by thermostat control. Standard units quickly installed in existing ducts . . . multiple circuits can be supplied for modulating heat output. Call your Chromalox representative or write today for details.

CHROMALOX Electric Heat

Edwin L. Wiegand Company
7575 Thomas Boulevard
Pittsburgh 8, Pa.

2644-A

Circle 484 on Page 19

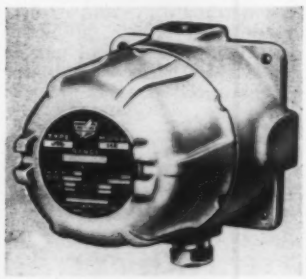
low audio and radio noise. Suitable for equipment drawing up to 100 va, it operates best at frequencies other than that of the available main power source. It is also recommended for use in testing equipment over a range of frequencies between 45 and 2000 cps. Low output distortion makes the unit an excellent servo supply. Wide output-frequency range permits it to be used in 60-cycle applications and also with higher frequency aircraft and missile components. Input voltage is 105 to 125 v at 45 to 65 cps; output voltage range is zero to 130 v with 1 per cent regulation for line or load. Ambient temperature range is zero to 40 C. **Sorensen & Co. Inc.**, Richards Ave., South Norwalk, Conn. B

Circle 677 on Page 19

Pressure Control

incorporates two separate switches

Type J96A explosionproof pressure control has two completely separate switches, permitting independent switch action above or below set point, control of two independent circuits, and flexibility of switching arrangement. It is designed for use in hazardous locations where explosive vapors and gases are present. Uncalibrated pressure settings can be made individually on each switch by adjusting screws after removing cover. Switches can be set together to simulate double-pole circuitry or set apart to obtain independent op-



HOW TO GET *MORE* FOR YOUR CASTING DOLLAR

Accurate analysis of your casting costs should include a thorough knowledge of the scope of your suppliers' operations. Monarch's new brochure gives you an informative guide to our modern manufacturing methods.

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- **Plant facilities and services**
- **Aluminum permanent mold castings**
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- **Mechanized diecast trimming**
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- **Custom finishing**
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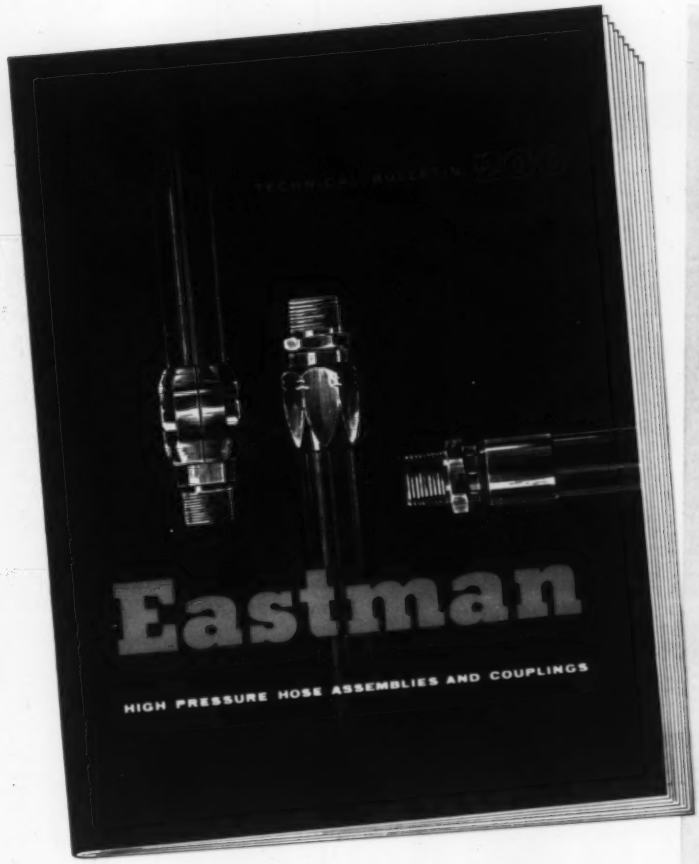
- **Casting engineering analysis**
- **Production control**

Send for your copy today.

MANUFACTURING in MOLTEN ACHIEVEMENTS ALUMINUM

MONARCH ALUMINUM MFG. COMPANY
9205 Detroit Avenue Cleveland 2, Ohio

Circle 485 on Page 19



CONVENIENTLY ARRANGED TO HELP YOU MEET THE INCREASING DEMAND FOR HIGHER PRESSURES

Here's an entirely new service concept in catalog arrangement. It is designed to assist Engineers and Purchasing Agents in specifying Multi-Braid Hydraulic Hose and Tube Assemblies to meet the demand for increasing pressure requirements. With pressure as a primary consideration—the right assembly can be selected for the specific equipment on which it is to be used.

Nine major sections are devoted to assemblies suited to all types of high pressure hydraulic applications—complete with tables and specifications, including easy to read dimensional cross section drawings.

Include this new catalog in your files to make it easier to specify the proper assemblies.

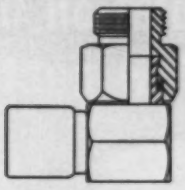
Write for Your Copy Today!

Eastman *first in the field* **MANUFACTURING COMPANY**
Dept. MD-5, MANITOWOC, WISCONSIN

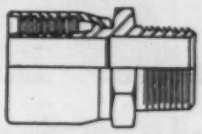
SAFEGUARDING AMERICA'S LIFELINES OF MOBILE POWER

AN INSIDE LOOK AT A *NEW BOOK*

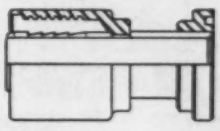
Eastman's new Technical Bulletin offers a new standard in simplified arrangement—for your convenience in specifying—according to your pressure requirements.



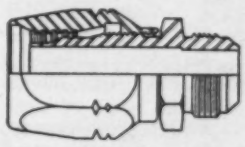
Swivel "O" Ring Male Couplings are available in 45° and 90° angles. Specifications on Page 13.



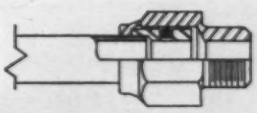
Permanently Attached Couplings for 2-wire braid hose. Specifications and Details on Page 10.



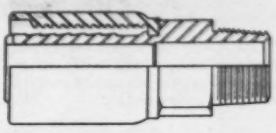
Permanently Attached Flange Head Couplings and Inserts from 0° to 90°. See complete list on Page 21.



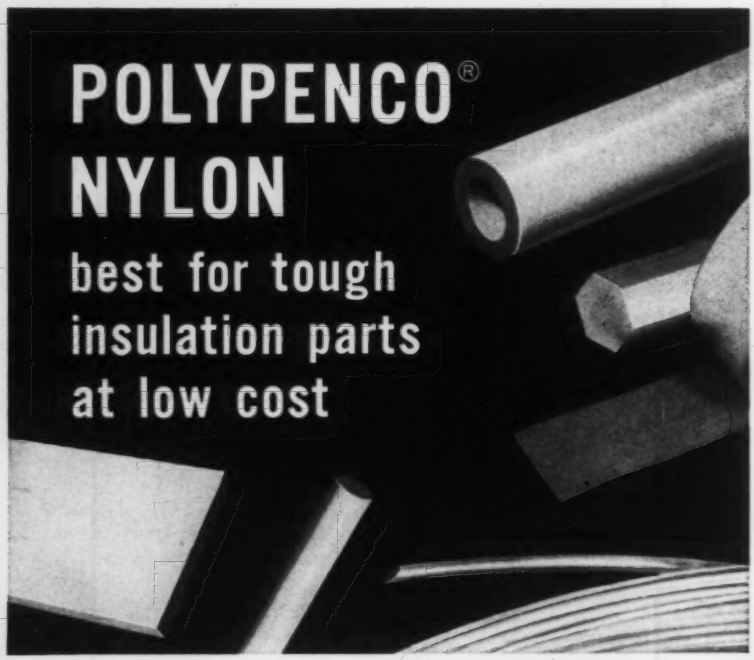
2-Piece Reusable Couplings for all high pressure hose. Used for pressures up to 5000 lbs. See Page 25.



Swivel Male Tube Nut "O" Ring Assembly used on formed tubing—described on Page 30.



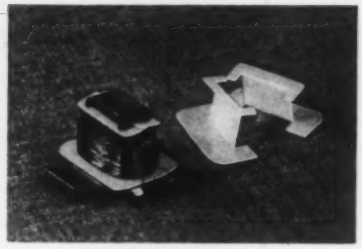
Permanently Attached Couplings for Extreme High Pressures up to 7000 lbs. working pressure, Page 12.



Unique properties of POLYPENCO Nylon combine insulation characteristics of plastics with mechanical strength of metals.

If your design requires high voltage and low frequency insulation at low cost, POLYPENCO Nylon should be your first consideration. Thousands of successful applications in the electrical industry . . . and in many others . . . have proven POLYPENCO Nylon's superiority over *other materials*.

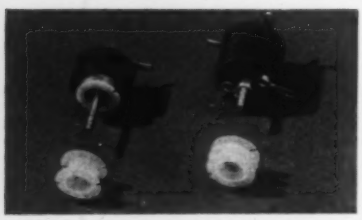
"*SONIC*" tested to detect porosity, POLYPENCO Nylon Shapes have uniform density, controlled hardness and toughness, and freedom from internal stresses. A complete range of stock shapes can be shipped immediately from warehouses located throughout the country.



For a "Flyback" transformer (above) operating at 21,000 volts, parts blanked from POLYPENCO Nylon strip efficiently shield current against corona attack.

Check this list of POLYPENCO Nylon features and join the fast growing number of designers who specify POLYPENCO.

- High wear resistance
- Low surface friction without lubrication
- Corrosion and chemical resistance
- Excellent resilience and toughness
- Non-galling and non-abrasive qualities
- Low cost machining and fabrication
- Consistent top quality
- Complete size range
- Immediate availability
- Custom fabrication service



POLYPENCO Nylon coil forms, machined to .015" thinness, permit adjustable magnetic cores to be in close proximity to wire coils wound on the nylon bobbins.

Write for latest data on product or services, or for technical assistance on your applications.

THE POLYMER CORPORATION OF PENNA.
Reading, Pennsylvania
Export: POLYPENCO, INC., Reading, Pa., U.S.A.

POLYPENCO

POLYPENCO Nylon, POLYPENCO Teflon*, NYLAFLOW® and NYLATRON® GS *DUPONT TRADEMARK

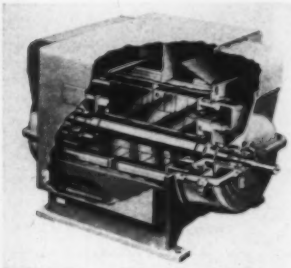
eration. Switch line includes normally open, normally closed, or double-throw types with no neutral position. Rated for 15 amp at 115 or 230 v ac, all switches are single pole and suitable for 180-F ambient temperature. **United Electric Controls Co.**, 79 School St., Watertown, Mass. B

Circle 678 on Page 19

Weather-Protected Motors

in ratings from 250 to 1500 hp

New motors, designed for outdoor operation under extreme weather conditions, are available in ratings from 250 to 1500 hp. Applications include use in the chemical, petroleum, paper processing, and public



utility industries, and in pipeline, boiler-feed pump, and other outdoor industrial applications. Ventilation system prevents entrance of windborne particles and moisture by forcing incoming airstream through a number of abrupt changes in direction and sharp decreases in velocity. Split-sleeve bearings and bearing brackets permit easy removal or inspection. Inspection ports are provided for observing oil rings while motor is operating. **Louis Allis Co.**, Dept. P, 427 E. Stewart St., Milwaukee 1, Wis. K

Circle 679 on Page 19

Teflon Tape

in thicknesses from 0.005 to 0.096 in.

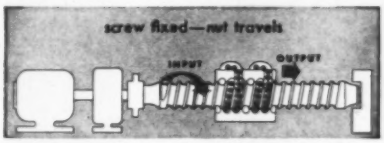
Teflon tape is now available in widths to 24 in. and thicknesses from 0.005 to 0.096 in. Tape, which has many industrial uses, is also available in a cementable form. **Garlock Packing Co., U. S. Gasket Co. Div.**, Camden 1, N. J. E

Circle 680 on Page 19

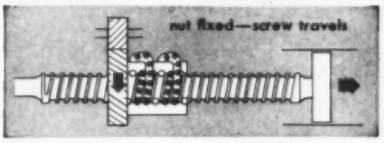
Here's your new ANSWER

PHOTOGRAPHED ACTUAL SIZE
BALL CIRCLE DIAMETER: 3/16 inch.

WORLD'S SMALLEST ball/bearing SCREW SOLVES CRITICAL MINIATURE POSITIONING/CONTROL PROBLEMS



NUT TRAVELS: When rotary motion is applied to the screw, the b/b nut glides along the axis of the screw on rolling steel balls, converting rotary force and motion to linear force and motion with 4/5 less torque than acme screws.



SCREW TRAVELS: When rotary motion is applied to the b/b nut, the screw glides along its longitudinal axis on rolling steel balls, converting rotary force and motion to linear force and motion with unprecedented efficiency.

An unprecedented achievement in minimum size and weight—maximum efficiency, dependability and service life for ultra-precise controls.

It's another first from Saginaw—and the possibilities it opens up for improved electrical and electronic controls are limited only by your imagination! Radar tuners, missile and rocket guidance and telemetering systems, automatic switchgear, electronic machinery controls are just a few of the applications where this new miniature Saginaw b/b Screw will solve critical positioning/control problems. *It's so compact and light*, you can save substantially on space and weight. *It's so efficient*, (over 90%) you can use much smaller motors and gear boxes. *It's so precise*, you can position components within .0005 inch per inch of travel. *It's so dependable*, you can rely on remarkably long service life even in adverse environments.

You will find our 1958 Engineering Data Book extremely helpful in planning applications, or experienced Saginaw engineers will gladly make specific recommendations without obligation. Just phone, write or mail the handy coupon.

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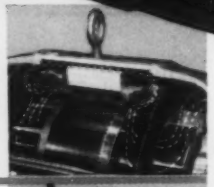
Saginaw ball/bearing Screw

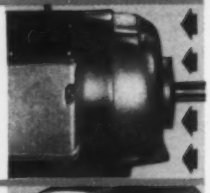
SAGINAW STEERING GEAR DIVISION • GENERAL MOTORS CORPORATION • SAGINAW, MICHIGAN

Circle 488 on Page 19

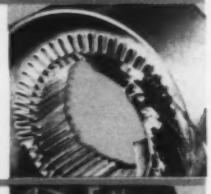
NEW R&M Re-Rated Series 254U All-Weather Motors



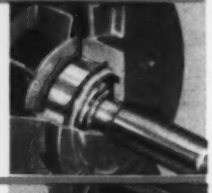
"straight through" dual-sweep ventilation eliminates "hot spots"



full height end head protection



Mylar insulation increases motor life*



bearings easily inspected by removing cover plate

permanently numbered leads simplify installation and maintenance

*DuPont registered trademark.

Premium Performance

. . . at standard motor prices

R&M Series 254U Motors help pay their own way from the minute you flip the switch! They stoutly resist any hostile environment—moisture, dirt, heat, acid or alkaline fumes—and so live longer. They have push-pull ventilation that won't let dirt settle and keeps motor internally cool—and so perform with full, brisk efficiency. Their oversize bearings are quick and easy to inspect and relubricate—so your maintenance costs dwindle.

This long, trouble-free, vigorous motor life is what R&M means by "Premium Performance"—an extra reward in service and savings every R&M motor offers. These and other big, money-saving advantages shown at left cost no more . . . R&M motors carry standard motor prices!

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ENGINEERING DEPARTMENT

EQUIPMENT

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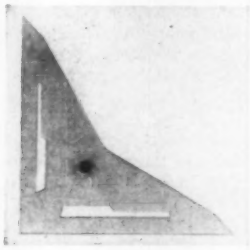
Triple-Angle triangle contains 45/90 and 30/60-deg angles and built-in slot lettering guides for 1/8, 1/4, 3/16, and 3/8 lettering. It is for use in layout, sketching, or



planning wherever limited equipment is available. Triangle is either clear or fluorescent acrylic plastic, 0.100 in. thick, in 8 and 10-in. sizes, and is equipped with convenient lifting knob. **Alvin & Co. Inc.**, Palisado Ave., Windsor, Conn. B

Circle 681 on Page 19

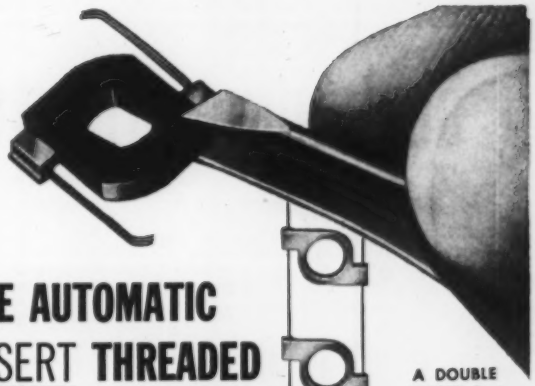
DC Power Supplies

include four 28-v units

Four new 28-v dc airborne and ground-support power supplies incorporate nonaging silicon rectifiers. Three of the units utilize three-phase, 400-cycle power input and the fourth, a 1-amp supply (shown), utilizes single-phase, 400-cycle input. The smallest unit has built-in fuse protection and high pulse-type overload capacity for relay or

(*Please turn to Page* 184)

another wonderful GRC idea for designers



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Zinc Alloy 1 1/2", 1/2 oz. • Plastic 1 1/4", .03 oz.

A DOUBLE INSERT Part, automatically produced

For this IBM Brush Assembly, the core is die cast automatically and continuously onto 6 strands of music wire, 3 on each side.

In the second cycle the nylon insulating jacket is molded automatically and continuously . . . right onto the die cast core and wire inserts.

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Circle 490 on Page 19

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Circle 491 on Page 19

DESIGNING WITH ALUMINUM

NO. 28

This is one of a series of information sheets that discuss the properties of aluminum and its alloys with relation to design. Extra or missing copies of the series supplied on request. Address: Advertising Dept., Kaiser Aluminum & Chemical Sales, Inc., Department PD-1, 919 N. Michigan Ave., Chicago 11, Ill.

CLEANING AND PROTECTING ALUMINUM SURFACES

To aid designers in recommending maintenance procedures for aluminum finishes, this article summarizes the recommended uses and methods of applying mechanical, chemical, proprietary and wax-lacquer materials.

THE SUBJECT of cleaning and maintaining aluminum is a departure from the usual content of this design series. But with the growing importance of *product finish*, the designer today is as much concerned with lasting beauty as with development of a product itself.

Four Types of Maintenance

In general, the methods and materials for cleaning and protecting aluminum surfaces may be divided into four groups or types: mechanical cleaning, chemical cleaning, treatment with cleaner-wax-polishes, and waxing or lacquering. In most cases, only one of these types will be required to return the aluminum to its original pleasing luster. In some instances, a combination of them may be necessary. As a rule of thumb, the mildest treatment that produces satisfactory results should be used.

The natural oxide film which is responsible for corrosion resistance forms rapidly on clean aluminum exposed to air. This self-healing action assures the natural corrosion resistance of aluminum within a short time after cleaning. An *anodized* aluminum surface is virtually impervious to atmospheric influences. However, should it be desirable to clean anodized aluminum, washing with a warm solution of a mild soap is usually all that is necessary. In the event that an exceptionally tenacious soil is encountered, a mild abrasive cleaner should be used.

1. MECHANICAL CLEANING

The simplest, and therefore the most common, method for removing dirt from aluminum surfaces is mechanical cleaning. Because of their action, soaps and detergents are included as cleaning agents under this group. Actually, many soiled aluminum structures and vehicles can be cleaned with nothing more than soap and water applied with a soft scrubbing brush. Strong detergent solutions, if not thoroughly rinsed, may cause surface staining. Rinse thoroughly, wipe dry with a clean cloth.

Mild abrasive cleansers—such as the household cleansing and scouring powders—are effective in cleaning aluminum. Application is made with a cloth dampened in water. Surface must be rinsed well and wiped dry. *Caution:* always work with the grain of the metal.

Steel wool—for harsher abrasion—must be carefully used on aluminum, rubbing in the direction of the metal grain and using only enough pressure to remove the soil. Heavy pressure will mar the mirror reflectivity of the surface. Special care must be taken with "satin" finished aluminum to prevent polishing of the etched satin finish. Stainless steel wool, 00 size or finer, is preferable for cleaning aluminum because it will not cause corrosion if slivers become embedded. If steel wool soap pads are used, the aluminum surface must be thoroughly rinsed to prevent rust discoloration from embedded slivers.

When using abrasives, always bear in mind that they may alter the appearance of the aluminum finish. To minimize such change, always rub in the direction of the finished grain—never across the grain. Special care should be exercised in cleaning matte finished aluminum which has no grain.

2. CHEMICAL CLEANING

The fastest and least expensive way to clean aluminum surfaces, especially large areas, is to use liquid chemical cleaners. These cleaners may be obtained ready-for-use or in a concentrated form that requires dilution with water or mineral spirits before application. Because they can be applied rapidly by swabbing or spraying, they have found ready acceptance in the aircraft and railroad industries.

Solvent cleaners—kerosene, turpentine and naphtha—are especially good for greasy deposits and for heavy accumulation of grime. It is a good practice to rinse off the solution to avoid streaks or deposits. If a surface has been lacquered, it may be cleaned with a mineral solvent or turpentine and a soft

When using abrasive cleaners of any kind, care must be taken to work with the grain of the aluminum surface to avoid marring mirror or satin finish.

Either paint-spray equipment or clean brushes may be used to apply protective lacquers. Before lacquering, surface should be prepared by etching-type cleaner.

cloth. A clean absorbent material should be used for drying. Non-etching type chemical cleaners—available under brand names in ready-to-use and in concentrated form—are the fastest and least expensive way to clean large aluminum areas.

Etching chemical cleaners—phosphoric acid type (*not* to be used on anodized aluminum)—are heavy duty cleaners to be used when all other methods fail. Etching chemical cleaners change the appearance of the finish and may permanently harm the aluminum surface unless thoroughly rinsed, especially out of cracks, corners and holes. Care should be exercised to see that there is no run-down on the aluminum outside the area being cleaned.

If cleaning is followed by waxing, a non-etching type cleaner is usually preferred. However, etching type chemical cleaners (generally having a phosphoric acid base) are most effective for surfaces that are subsequently lacquered. The degree of etching can be controlled somewhat by the length of time that the cleaner is left on the aluminum surface. Manufacturers' directions should be followed carefully when using chemical cleaners. Chemicals left too long in contact with the aluminum surface may have a corrosive effect. Therefore, rinsing must be liberal and thorough.

Steam is an excellent mild treatment for removing dirt, grease deposits and common atmospheric soil. If cleaning additives are used, strong alkaline solutions are to be avoided. Following steam cleaning, surface should be rinsed thoroughly with clean water and dried with a clean cloth. Make sure there is no collection of moisture at the bottom edges of the aluminum.

3. CLEANER-WAX-POLISHES

Using any of the proprietary cleaner-wax-polishes which are available requires somewhat more time than either mechanical or chemical cleaning. However, despite the greater labor, they are not difficult to apply. Furthermore, they provide a limited amount of surface protection, and thus may eliminate the need for a waxing operation if cleaning is to be done on a frequent schedule.

Wax-base polish cleaners should be applied with a clean, soft cloth as directed by the manufacturer. The thin protective coating need not be removed unless the aluminum surface is to be lacquered. Because of the wax content, these products should be applied indoors or in shade. When working with large objects, a mechanical buffer is of great assistance. Because of the mildness of the abrasive, this type of cleaner is one of the safest for use on aluminum. Non-wax-base polish cleaners—such as used for cleaning glass—are satisfactory for cleaning aluminum, and abrasive waxes of the type used for cleaning metal tableware are effective in removing atmospheric grime deposits.

4. PROTECTIVE WAXES AND LACQUERS

Unless aluminum structures or vehicles can be cleaned at regular, frequent intervals, the metal surfaces should be protected against the discoloring effects of severe environments or travel grime. Waxing is the cheapest and simplest way to do this. Suitable waxes are available in either paste or liquid form. Generally, waxed aluminum surfaces can be cleaned by merely wiping them with a damp cloth. They may be rewaxed over previous wax coats that have been cleaned, but in time this built-up coating will yellow. When this happens, the wax should be removed with a solvent or a mild abrasive cleaner before further waxing.

A relatively permanent colorless protective coating on aluminum is given by one or two coats of clear methacrylate lacquer. This lacquer coating can best be applied with a spray gun. However, formulations for brush application are also available.

The best lacquering results are obtained by first cleaning the aluminum surface (except anodized surfaces which require no preparation) with an etching-type cleaner. A solution of one part cleaner to three parts water will provide a good "tooth" on the aluminum surface for better lacquer adhesion. Apply the solution over a small area that can be kept wet for three to five minutes. Before solution dries, flush surface with clean water—paying particular attention to cracks, grooves, corners and holes. Dry thoroughly. Swabbing with a half-and-half solution of denatured or wood alcohol and water will hasten drying.

Like all exterior surfaces, aluminum will collect air-borne dust and grime. Regular periodic cleaning will help preserve the appearance of any finish.

NOTE: Upon your request for reprints of this advertisement, we will also send you a brochure containing a list of materials suitable for cleaning and protecting aluminum. (These materials have been evaluated by Kaiser Aluminum's Department of Metallurgical Research, but inclusion in the list does not constitute an endorsement or preference over similar materials intended for the same purpose.)

And for further information and assistance concerning specific problems in cleaning and protecting aluminum surfaces, contact the Kaiser Aluminum sales office or distributor listed in your telephone directory. Kaiser Aluminum & Chemical Sales, Inc., *General Sales Office*, Palmolive Bldg., Chicago 11, Ill.

see our catalog in PRODUCT DESIGN FILE or write for copy

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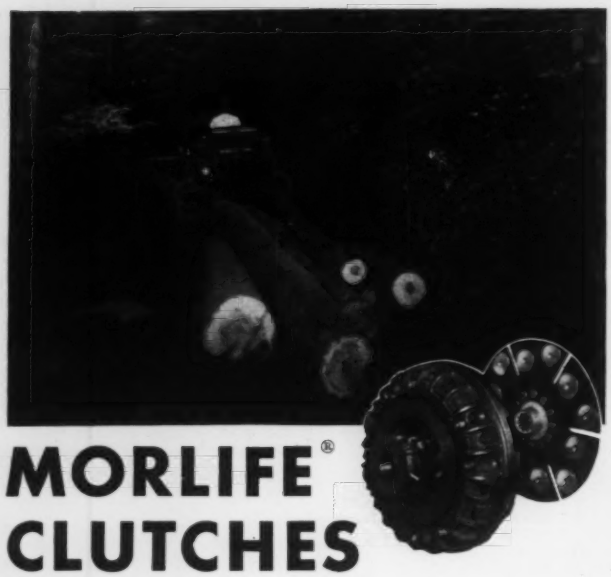

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Compared to previous type clutch facings, Morlife® Clutch facings reduce hand-lever pull up to 50%. They assure positive engagement—with power-holding grip. Provide a degree of heat resistance and dissipation never before available. They give four times the durability for prolonging clutch life and extend the time between adjustments ten times as long. Let ROCKFORD clutch engineers show you how these new advantages will improve the operating ease and prolong the on-the-job life of *your* product.

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CLUTCHES

Circle 493 on Page 19

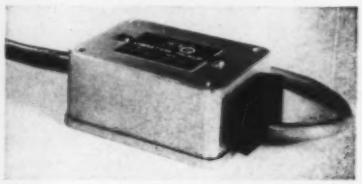
(*Continued from Page* 181)

solenoid applications. The three larger units are a 100-amp silicon transformer-rectifier, a 200-amp airborne power supply, and a 200-amp, 28-v dc supply for missile-support applications. .**General Electric Co.**, 1 River Rd., Schenectady 5, N. Y. C

Circle 682 on Page 19

Vibration Pickups

in damped and undamped models



Series TD vibration pickups, using a new magnetic circuit, combine the temperature stability of magnetic damping with sensitivity of over 300 mv per in. per sec. Five models provide natural frequencies from 1.8 to 5.6 cps and response to 2500 cps on undamped and 1500 cps on damped units. Weight of each unit is 9 oz. **Southwestern Industrial Electronics Co.**, P. O. Box 13058, Houston 19, Tex. I

Circle 683 on Page 19

Thermocouple Vacuum Gage

nonlinear scale has range of 0 to 1000 mu Hg

GTC-100 two-station thermocouple vacuum gage measures total pressure in a vacuum system on a single nonlinear scale with range from 0 to 1000 mu Hg. Unit is obtainable with one or two sensing tubes for use as a one or two-station gage. Printed circuitry provides smaller, more compact package than previous models. **Rochester Div., Consolidated Electrodynamics Corp.**, 1175 Mt. Read Blvd., Rochester 3, N. Y. F

Circle 684 on Page 19

Take a new look at

ZIRCONIUM

Now zirconium takes another giant step ... from an expensive rarity to a readily available special-purpose metal. Capacity is now on hand for not only A.E.C. requirements but also commercial markets. And, as in titanium, Mallory-Sharon is in the forefront of this rapid development.

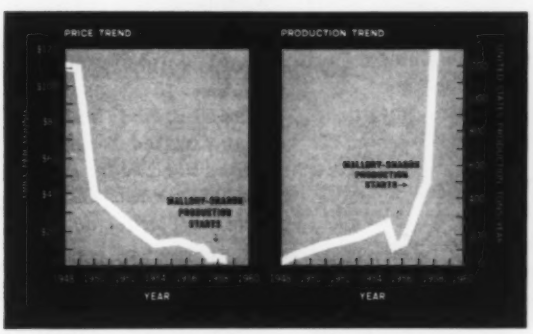
A modern, highly efficient zirconium and titanium sponge plant at Ashtabula, Ohio, now makes Mallory-Sharon the largest single source of metallic zirconium, and its by-product, hafnium.

Mallory-Sharon's integrated production facilities ... from raw materials through finished mill products ... mean *greater availability* and *lower costs*.

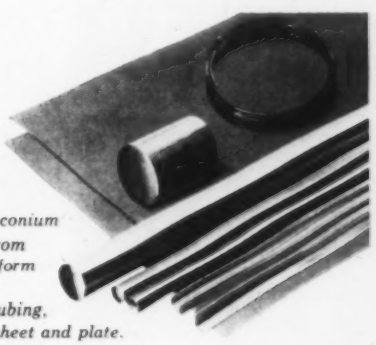
We're ready *now* to help you explore practical commercial uses for zirconium. Write us for technical information, or engineering assistance on specific applications.

For technical facts – *Write for new 16-page booklet, giving technical and application data on zirconium ... its excellent corrosion resistance to most acids, alkalies and combinations of these media ... its remarkable nuclear properties.*

For availability – *As Mallory-Sharon's large, modern, sponge plant reaches full production this year, zirconium becomes readily available for all commercial applications.*



For lower prices – *Greater availability will definitely be reflected in lower prices. In many cases, the improved performance of zirconium parts much more than offsets their higher material cost.*



For mill products – *Zirconium is now available from Mallory-Sharon in the form of rounds, bars and billets, wire, tubing, strip, foil, sheet and plate. Quality and properties are carefully controlled at every stage of production.*

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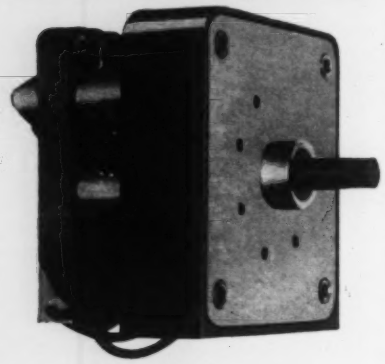

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Please send me literature and prices on Heinze Gearmotors.

Name & Title.....

Company.....

Street & No.....

City & State.....

Circle 496 on Page 19

THE ENGINEER'S Library

Recent Books

Analysis and Control of Nonlinear Systems. *By Y. H. Ku, Professor of Electrical Engineering, University of Pennsylvania; 360 pages, 6 by 9 in., clothbound; published by The Ronald Press Company, 15 East 26th St., New York 10, N. Y.; available from* MACHINE DESIGN, *$10.00 per copy postpaid.*

Analytical and topological methods of solving nonlinear differential equations are presented in this book, which covers mechanical vibrations and electrical oscillations. Physical examples are worked out in detail for both mechanical and electrical systems.

Basic Feedback Control System Design. *By C. J. Savant Jr., Director of Engineering, American Electronics Inc.; 418 pages, 6 by 9 in., clothbound; published by McGraw-Hill Book Company Inc., 330 West 42nd St., New York 36, N. Y.; available from* MACHINE DESIGN, *$9.50 per copy postpaid.*

The fundamentals of servomechanism theory and design are explained in this book and are exemplified by practical examples. Procedures are discussed for obtaining the differential equations of mechanical systems, networks and couplings, as well as for electrical networks.

Although emphasis is placed on linear servomechanism design, a chapter is included on nonlinear servo analysis. The components of servo systems are discussed from the point of view of their use in system design rather than their individual operation.

Effects of Radiation on Materials. *Edited by J. J. Harwood, U. S. Office of Naval Research; 355 pages, 6 by 9 in., clothbound; published by Reinhold Publishing Corp., 430 Park Avenue, New York 22, N. Y.; available from* MACHINE DESIGN, *$10.50 per copy postpaid.*

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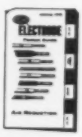

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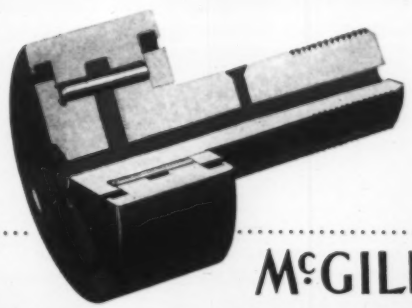
only McGILL® sealed CAMROL® cam followers give you . . .

effective sealing

prelubrication

high radial and shock capacity

in a full range of sizes



Effective sealing of the CAMROL cam follower against moisture, dirt, chips, etc. guarantees longer service life . . . reduces maintenance. This sealed construction retains lubricant and eliminates need for frequent relubrication, so often undesirable in cam action, guide support and track roller applications.

Special seals are built in at stud and flange ends. A black oxide finish on all exposed surfaces offers outside corrosion resistance. The channeled reservoir above the rollers in the outer raceway bore helps store reserve lubricant, sufficient in most cases for lifetime service. Relubrication is possible through convenient oil holes. The new SCF sealed CAMROL cam followers interchange with proven standard CAMROL cam followers. Standard stock with roll diameters up to 4" are available for both stud and shaft mounting.

For maximum bearing life where contamination is a problem, specify sealed CAMROL cam followers. Ask your McGill representative or our engineering department for recommendations.

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changes radiation produces in metals, ceramics, and plastics. The treatment of these effects is divided into two major fields.

Discussion in the first category pertains to the influence of radiation on physical, metallurgical, corrosive, surface, electronic, and optical properties in general. The second covers the behavior of substances such as semiconductors, metals, cores, liquid coolants, control rods, organic materials, and polymers in irradiation environments.

Feedback Control Systems. *By Otto J. M. Smith, Professor of Electrical Engineering, University of California, Berkeley; 694 pages, 6 by 9 in., clothbound; published by McGraw-Hill Book Co. Inc., 330 West 42nd St., New York 36, N. Y.; available from* MACHINE DESIGN, *$13.50 per copy postpaid.*

The principles underlying the analysis and design of all types of feedback control systems, linear and nonlinear, are presented in this book which discusses the prediction of closed-loop characteristics and determination of required components.

New Standards

ASTM Standards on Iron Castings. *168 pages, 6 by 9 in., paperbound; published by and available from American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.; $2.75 per copy.*

Contained in this volume are all 32 ASTM standards relating to pig iron, gray-iron castings, cast iron pipe, nodular-iron castings, malleable-iron castings, welding rods and electrodes, and general methods of test.

Standards of the Steatite Manufacturers Association. *24 pages, 8½ by 11 in., paperbound; published by and available from Steatite Manufacturers Association, 53 Park Place, New York 7, N. Y.; $1.00 per copy.*

This edition of the standards contains information concerning the various grades, composition, electrical properties, uses, and methods of testing steatites, which are kiln-fired ceramic insulating bodies, composed chiefly of magnesium silicate crystals.

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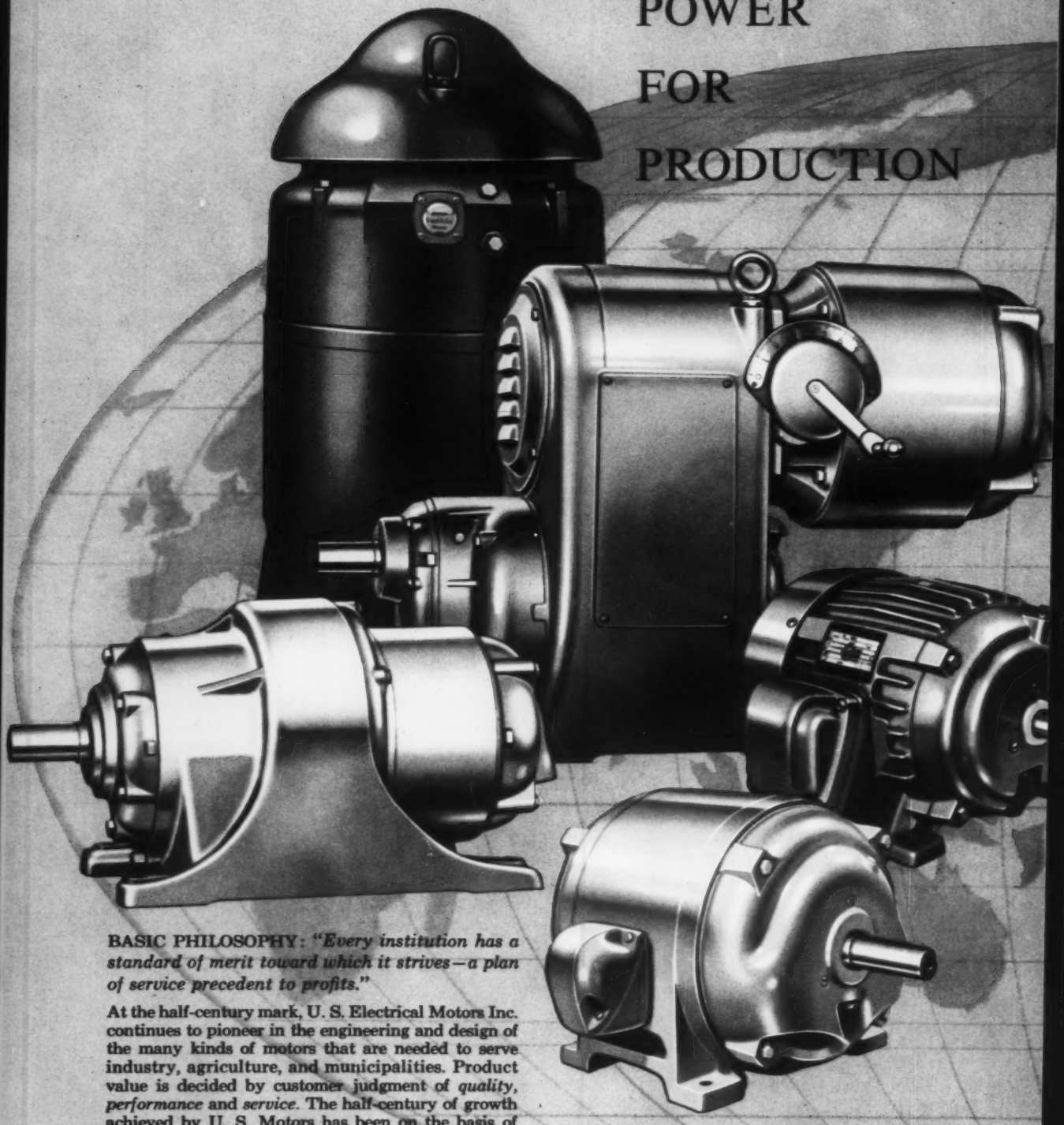
HALF A CENTURY OF POWER FOR PRODUCTION



BASIC PHILOSOPHY: *"Every institution has a standard of merit toward which it strives—a plan of service precedent to profits."*

At the half-century mark, U. S. Electrical Motors Inc. continues to pioneer in the engineering and design of the many kinds of motors that are needed to serve industry, agriculture, and municipalities. Product value is decided by customer judgment of *quality*, *performance* and *service*. The half-century of growth achieved by U. S. Motors has been on the basis of that judgment by its customers.

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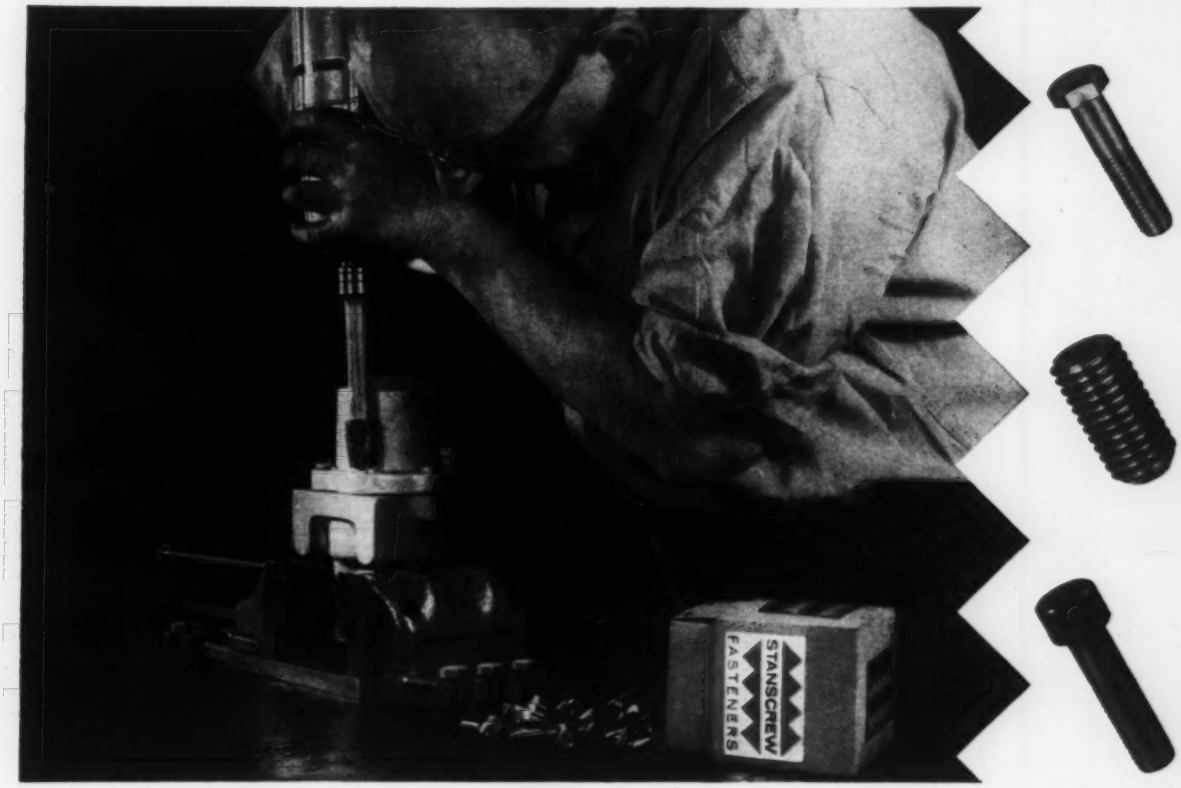
IT PAYS TO STANDARDIZE ON **STANSCREW**



Stanscrew service cuts rejects, speeds assembly for valve manufacturer

A prominent manufacturer of 4-way valves for freon was having trouble on his assembly line. His fasteners, tightened to an extreme degree to prevent seepage of the gas, were breaking on too many occasions. This meant complications in assembly and a high reject rate—which increased production costs substantially.

One of Stanscrew's fastener specialists, called in by a Stanscrew distributor, quickly found the answer. He recommended a standard cap screw and had staff engineers work out the precise torque which should be applied to insure a complete seal at all gaskets, yet eliminate any possibility of fastener breakage. By following these recommendations, the manufacturer has eliminated the problem of fastener breakage, and substantially reduced his reject rate.

Stanscrew offers over 4,000 standard fasteners . . . including a complete selection of socket, set, and cap screws. All are produced under rigid quality control methods and incorporate the lessons learned during 85 years of fastener manufacture. All 4,000 are always in stock and quickly available.

For the answer to your fastener problem, call your Stanscrew distributor. He will have a Stanscrew fastener specialist promptly study your operation and make specific recommendations.

STANSCREW FASTENERS

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HMS | HARTFORD MACHINE SCREW COMPANY, HARTFORD, CONNECTICUT
WESTERN | THE WESTERN AUTOMATIC MACHINE SCREW COMPANY, ELYRIA, OHIO

STANDARD SCREW COMPANY 2701 Washington Boulevard, Bellwood, Illinois

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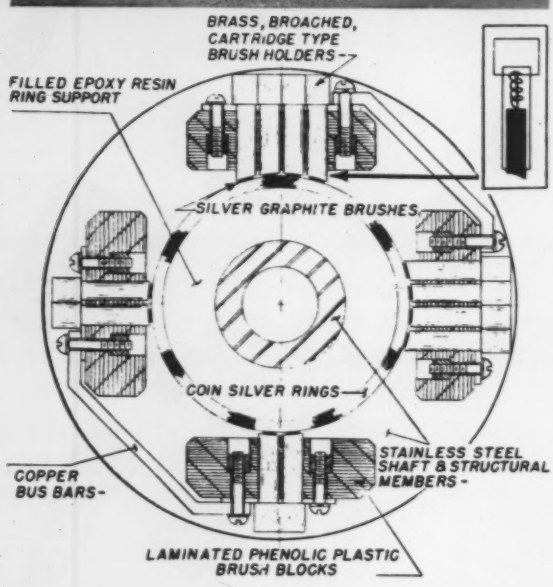
COMPLETE SLIP RING ASSEMBLIES
CONTACTS • BRUSHES • ALL COMPONENTS


BRASS, BROACHED, CARTRIDGE TYPE BRUSH HOLDERS
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SILVER GRAPHITE BRUSHES
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STAINLESS STEEL SHAFT & STRUCTURAL MEMBERS
COPPER BUS BARS
LAMINATED PHENOLIC PLASTIC BRUSH BLOCKS

The drawing above suggests how thoroughly the Superior staff works out every detail of a job. Superior will design and build any or all parts of a brush assembly, *OR* we will build to your design.

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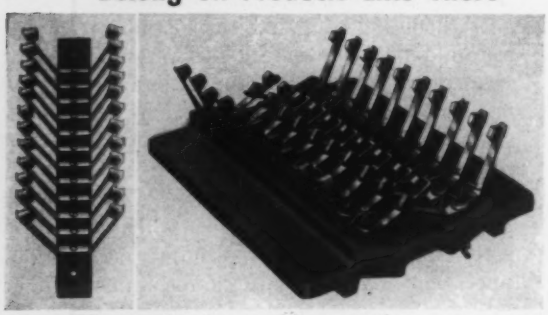
Superior Brush Contacts Belong on Products Like These



Slip ring brush assemblies, cantilever type.

Superior CARBON PRODUCTS, INC.
9115 GEORGE AVENUE • CLEVELAND 5, OHIO

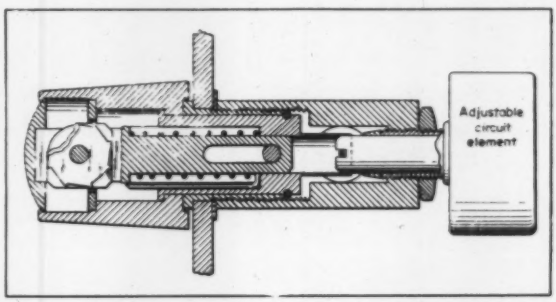
BRUSHES • CONTACTS • SLIP RING ASSEMBLIES
POWDER METAL PARTS • MECHANICAL CARBONS

NOTEWORTHY

Patents

Tamper-Proof Control Knob

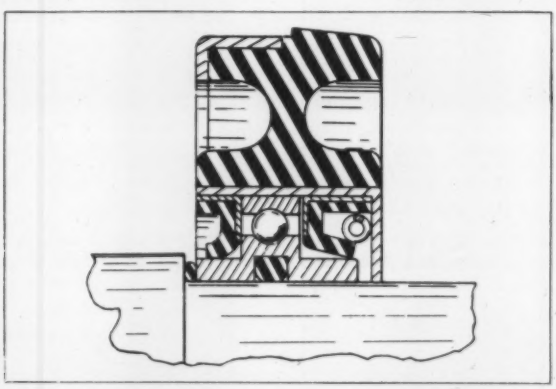
Possibility of unintentional or unauthorized change in the setting of an adjustable circuit element is minimized by a tamper-proof control knob. Designed for use with manually adjustable tuning condensers, potentiometers, and similar circuit components, the



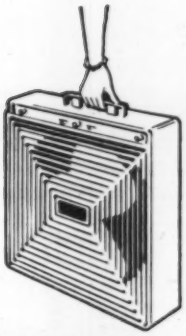
knob incorporates a built-in clutch which is engaged and disengaged by the actuation of a pushbutton mounted concentrically with the knob end. When engaged, the clutch transfers motion of the knob to the circuit component. After the component setting has been completed, pressure on the pushbutton disengages the knob. Condition of the clutch, while evident to the initiated, is not apparent to the casual observer. *Patent* 2,818,748 *assigned to Melpar Inc., Alexandria, Va., by Axel A. Lawson and Chester W. Ross.*

Floating Radial-Type Seal

Seal-lip flexure due to eccentric rotation between a shaft and a seal bore is eliminated in a floating seal with an integral, friction-reducing ball bearing. Deflection of a necked-down elastomer member, which separates the seal outer casing from the dynamic seal rings, maintains concentricity of bearing inner-race



Another example of RICHARDSON PLASTICS ENGINEERING SERVICES



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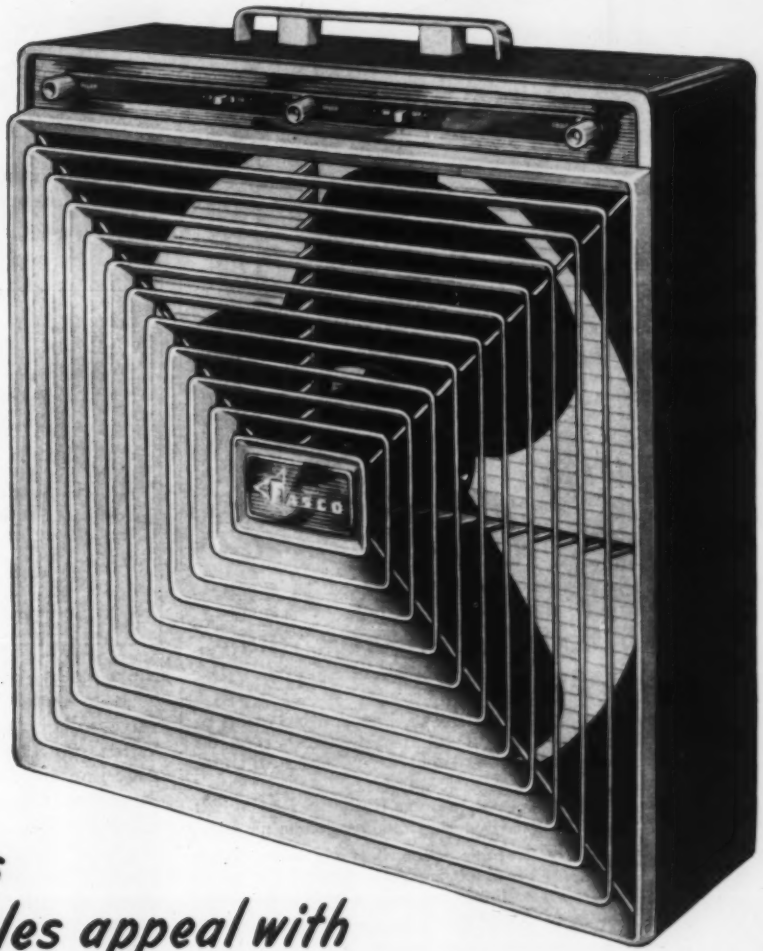

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PLASTICS MOLDED by RICHARDSON

Fasco Industries of Rochester, New York, chose Richardson to mold the fan diffuser guard for their new 20" portable fan shown above. One of the main reasons was the Engineering Service which helped to create a better product and additional sales appeal.

Working closely with Fasco engineers and Van Dyck Associates, designers of the unit, Richardson helped to develop the guard design for proper diffusion of air with the least amount of wind noises or vibration; the greatest strength for safety under all conditions; recommended the high impact polystyrene material; and created a mold which made all these features possible. The mold is a masterpiece of tooling and mold engineering.

This cooperative engineering service is available to you. The next time you are planning a new product or redesigning an old one, call Richardson. Our knowledge and experience in plastics engineering may save you money and will certainly give you a better product. Plan for tomorrow . . . send for the Molded Catalog today.

100 YEARS OF EXPERIENCE AND IMAGINATION 1858-1958

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LAMINATED and MOLDED

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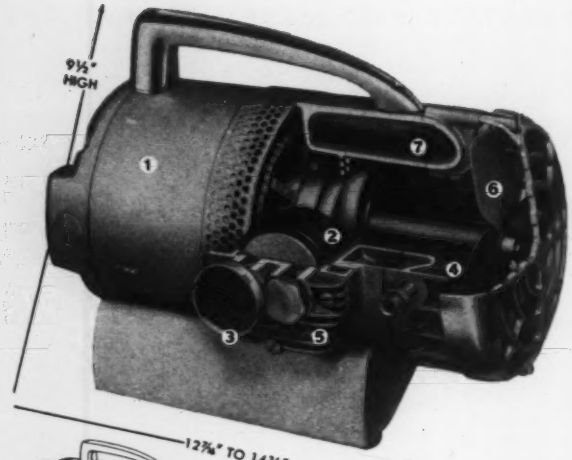


Oil-Free COMPRESSED AIR

CLEAN, COOL, DRY... FROM THIS PORTABLE OR BUILT-IN UNIT

Here is a compressor which doesn't need lubrication of any kind—eliminates an oil separator—*ends expensive lubrication maintenance*. Where else can you find all these features—

Easily carried portable model.

"Duplex Unit," mounted on horizontal tank.

1 **Special motors.** Built by B&G—ball bearings *permanently* grease packed.

2 **Graphite piston rings and skirts.** Never need lubrication—operate for years without destroying mirror-finish of cylinder walls.

3 **Dry valve construction.** Inlet and exhaust valves are positive sealing without presence of oil.

4 **Safety valve.** (Not visible.) Provides constant bleed-off at maximum pressure.

5 **Bi-metal cylinder head.** Transfers heat faster—shrink-fitted around cast iron cylinder.

6 **Blast cooled.** Low temperature operation assures higher efficiency, longer life.

7 **Combined aftercooler, pulsation chamber, moisture separator.** Assures cooler, drier air at uniform pressure.

B&G Compressor built into dry cleaning machine.

B&G Oil-less Compressors are available in a complete line of portable tank-mounted and tankless models. Send for catalog GO-1156.

Oil-less AIR COMPRESSORS

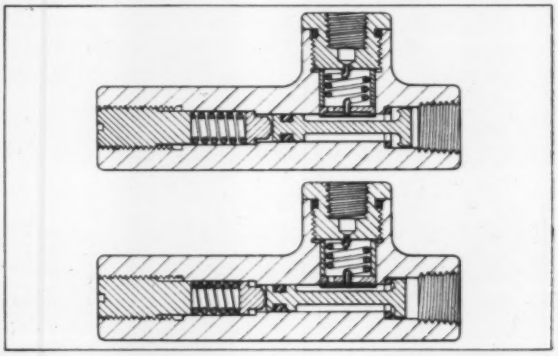
BELL & GOSSETT COMPANY

Dept. FG67, Morton Grove, Illinois

flanges and seal rings regardless of eccentricity of shaft rotation. Design is particularly adaptable for use with large-diameter shafts. *Patent* 2,823,966 *assigned to Federal-Mogul-Bower Bearings Inc., Detroit, Mich., by Noel S. Reynolds.*

Pressure-Gage Protector Valve

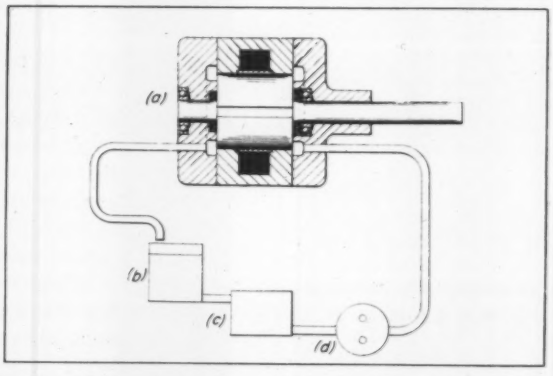
Damage to hydraulic pressure gages by high-amplitude pressure surges or excess static pressures is prevented by a protector valve incorporating an integral



choke coil. Upper section view shows valve shuttle open to permit passage of pressurized fluid from the valve inlet (right end) to the gage-connection port. When protector valve is open, pressure surges in the gage line are damped out by a choke coil in the valve T-section. Should static pressure exceed the setting of the shuttle loading spring, the shuttle moves left, isolating the gage from the pressure source. *Patent* 2,824,573 *assigned to American Associates Inc., Providence, R. I., by Walker Mason and Stephen J. Biello.*

Circulating-Fluid Magnetic Brake

Rated capacities of magnetic-fluid clutches or brakes are substantially increased by a design employing continuous circulation of the fluid through an external



heat exchanger. Circuit schematic shown here illustrates: *a*, magnetic-fluid brake; *b*, magnetic-fluid reservoir; *c*, heat exchanger; *d*, circulating pump. Tendency of fluid to concentrate in brake clearances and block flow when the unit is energized is eliminated by a bypass slot cut through the brake rotor. High rate

Applying Reliance V*S Drives in Designing Web-fed Equipment

by:
C. E. Robinson, E.E.
Section Manager
Application Engineering Dept.
Reliance Electric & Engineering Co.

A primary consideration on web-fed equipment is to maintain web continuity. If too much tension is exerted, the web will stretch or break, causing product imperfection or requiring machine rethreading. Too little tension will cause wrinkling or slack pile-up.

Reliance V*S Drives are ideal for driving and controlling web-fed processing equipment. Acceleration and deceleration rates can be programmed to prevent over and under tensioning during speed change, a critical condition for web-fed operations. Motor operating speeds can be automatically regulated to maintain correct tension under any conditions, even dead stall.

STARTING AND STOPPING PROTECTION

Figure 1 shows a typical operating cycle of a specialty printing press. This press prints and die cuts milk cartons. Paper stock is fed from a roll, and printing is done on a continuous web of paper.

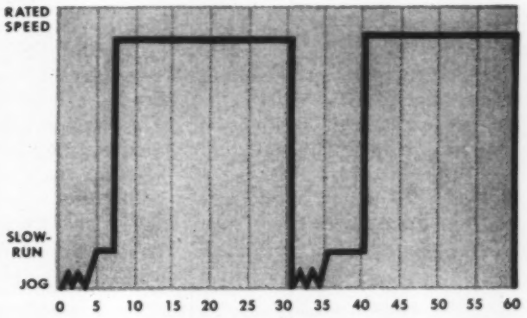


FIG. 1

A 30 hp. V*S Drive powers the press, providing speeds from jog and slow-run up to full operating speed. Speed changing is stepless and the rate of change is carefully regulated by a Reliance VSC exciter. The VSC applies voltage gradually to the motor, providing preset, automatic, linear acceleration. This press starts and stops about three times an hour. Any tearing or looping of the paper would seriously decrease production. The V*S Drive eliminates this danger.

TENSION CONTROL DURING OPERATION

Figure 2 shows a comparison between line speed and motor speed on the beamer of a textile slasher. In order to prepare the thread for weaving on the loom, it is put through a slashing operation. This consists of immersing thousands of individual strands in hot sizing, and winding them onto a wide roll or beam. Between the bath and the beamer are delivery rolls to tension the threads as they are wound.

A 5 hp. V*S drives the beamer, keeping unvarying tension on the delicate threads. Drive motor speed decreases during winding, maintaining constant tension as the roll builds. A Reliance VSR Regulator, through a feed-back loop, measures and controls the current drawn by the motor. As the beam builds up, the motor tries to draw more current. By keeping the current constant, the motor slows down in direct relationship to the build up of the beam. The V*S Drive will hold a constant tension from start to stop. If a mechanical jam should stop the slasher, the VSR will maintain tension even with the motor stalled.

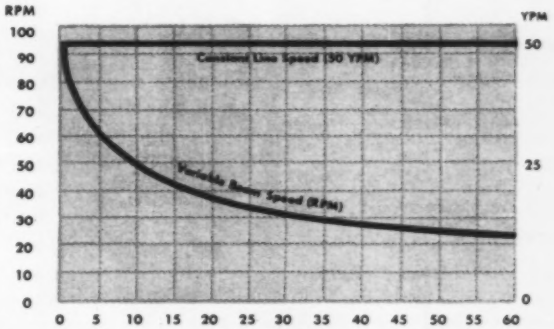


FIG. 2

V*S DRIVE COMPONENTS

A V*S Drive operates from standard a-c. power lines and consists of three basic components: d-c. drive motor, packaged motor controls and operator's control station.

Reliance drive motors change speed over a wide range, smoothly and without speed steps. The all electric design permits the inclusion of built-in dynamic or regenerative braking, giving fast, maintenance-free stopping power.

Motor-generator sets or electronic rectifiers, working from plant a-c. power lines, form the nucleus of the motor control unit. A series of built-in controls regulate voltage and current in the system. With these controls, any required combination of speed, horsepower, torque and time characteristics are produced.

If you would like further information on how you can use V*S Drives when designing your product, contact your local Reliance representative, or write for Bulletin No. D-2506. D-1548

RELIANCE ELECTRIC AND ENGINEERING CO.
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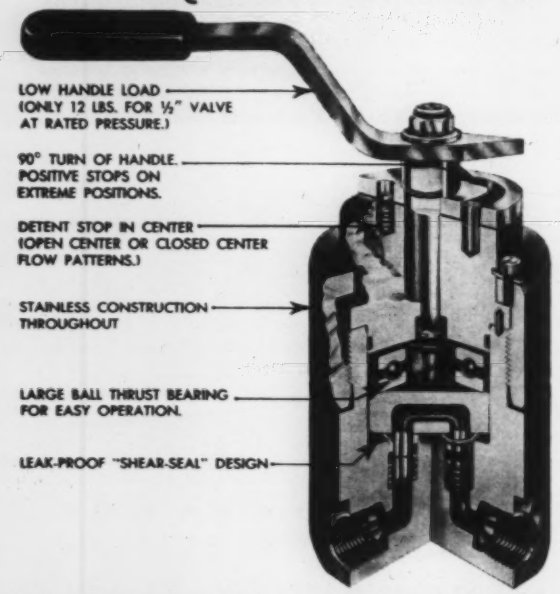
4 WAY VALVE

FOR LIQUIDS OR GASES


LOW HANDLE LOAD (ONLY 12 LBS. FOR ½" VALVE AT RATED PRESSURE.)
90° TURN OF HANDLE. POSITIVE STOPS ON EXTREME POSITIONS.
DETENT STOP IN CENTER (OPEN CENTER OR CLOSED CENTER FLOW PATTERNS.)
STAINLESS CONSTRUCTION THROUGHOUT
LARGE BALL THRUST BEARING FOR EASY OPERATION.
LEAK-PROOF "SHEAR-SEAL" DESIGN

This new four-way valve series comes in pipe sizes from ¼ to 1 inch, but may be obtained with tube, AND 10050, or any preferred special high pressure connection. It will withstand surges of up to 15,000 P.S.I. without damage to the valve's sealing qualities. It is designed for a burst pressure of 30,000 P.S.I.

No port to port leakage occurs in the detented positions because of the exclusive "Shear-Seal" design.

Long, maintenance-free service is assured because the optically flat metal to metal sealing surfaces of the sealing rings and mating rotor faces are protected by staying in constant intimate contact; flow is always through the center of the "Shear-Seal", never across sealing surfaces (as in conventional valve design). Sealing qualities actually improve as the self aligning "Shear-Seals" lap themselves to a more perfect fit with each valve operation.

Of course, there is no external shaft leakage, because the pressure is confined to the flow passages.

Write for Catalog 58-59

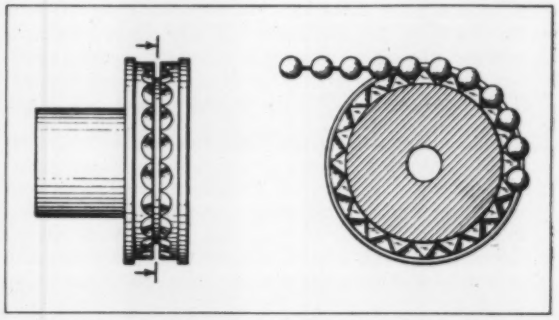
CONTROL VALVE DIVISION **Barksdale valves**

5125 ALCOA AVENUE • LOS ANGELES 58 • CALIFORNIA

of heat dissipation attained by the unit allows use of water in place of relatively expensive oils as carrier for the magnetic particles. *Patent 2,824,634 assigned to Raymond Engineering Laboratory Inc., Middletown, Conn., by Horace H. Raymond.*

Bead-Chain Drive

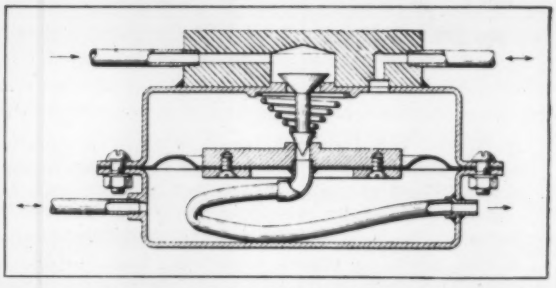
Conical sockets, with spacing proportional to sprocket pitch diameter, give smooth power transmission at high speeds in a bead-chain drive assembly. Sprocket design



automatically compensates for pitch differences between beads on straight section of chain and those passing around the sprocket. Entry of beads into sockets occurs without interference or hesitation common to bead-chain drives employing hemispherical sockets. *Patent 2,825,231 assigned to Voland and Sons Inc., New Rochelle, N. Y., by Bernard Wasko.*

Pilot Valve

Designed for use in pneumatic force balance systems, a "pneumatic relay" pilot valve throttles a constant-pressure air source in proportion to a variable signal pressure. In configuration shown here, constant-pressure air (inlet port, upper left) is throttled through a spring-loaded poppet valve to the upper, pressure-controlled chamber (exit port, upper right). Pilot or signal

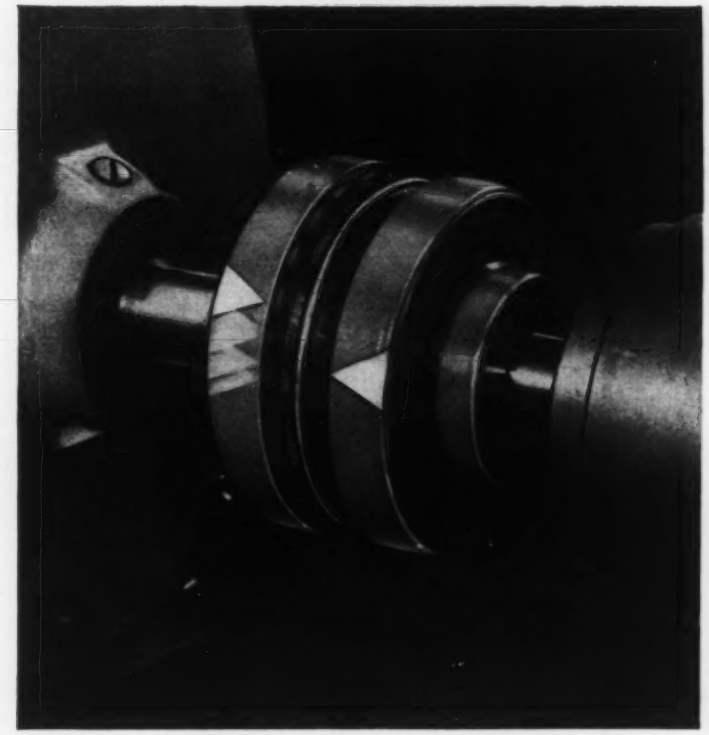


pressure is fed to the feedback chamber through the port at lower left. Pressure differential across the diaphragm separating upper and lower chambers raises or lowers the poppet valve, connecting the controlled-pressure chamber either to the source line, or to the flexible atmospheric bleed line. Result is to establish proportionality between supply and signal pressures. *Patent 2,825,354 assigned to Minneapolis-Honeywell Regulator Co., Minneapolis, Minn., by Robert C. Du Bois.*

NEW SURE-FLEX COUPLINGS

ABSORB 5 TO 15 TIMES MORE SHOCK

BOOST MOTOR AND MACHINE LIFE



Wood's new Sure-Flex Couplings have exceptional torsional flexibility . . . 15° at peak torque as compared to 1° to 3° for other types. They absorb from 5 to 15 times more shock and vibration than other leading flexible couplings, resulting in increased motor and machine life.

Sure-Flex Couplings are simply designed, sturdily constructed and easy to install. There are only 4 basic parts . . . 2 flanges and a 2-piece flexible rubber sleeve. The teeth of the sleeve halves lock into the teeth of the flanges without clamps or screws, tightening securely under torque to provide smooth, dependable power transmission.

Sure-Flex Couplings withstand all types and combinations of misalignment and end-float without wear or high resisting forces. Since all flexing takes place within the rubber sleeve, misalignment will not generate destructive unbalance or pulsations. There is no downtime . . . no need for lubrication or maintenance.

Write for Bulletin 10100. It is filled with helpful application data and additional information about Sure-Flex Couplings.

Wherever You Need Power . . .

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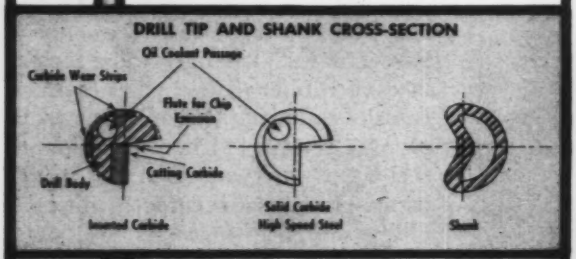
THIS DRILL ELIMINATES SECONDARY OPERATIONS

Just *one* pass with these high-speed steel or carbide-tipped gun drills produces an accurate, truly round, straight hole honed to mirror-bright finish. That's why you can drill small parts of all kinds — *faster, more accurately* and at *lower cost* with HI-STANDARD Gun Drills*.

Production parts that once had to be drilled individually can now be gang-nested and drilled through, producing holes identical in size, location and finish. Drilling of this kind is done on automatic indexing machines, lathes, horizontal and upright drilling machines, and similar equipment. Forced oil feed through the drill clears chips and cools cutting edge for faster drilling. No matter what the size or shape of your workpiece, drilling with HI-STANDARD Gun Drills is an



outstanding time-and-money saver. Any material that can be *machined*, can be *gun-drilled*.

Gun drilling is one important way in which forward-thinking manufacturers are increasing production and cutting costs. To find out how your company can do the same, write for your Hi-Standard Engineering File 20 *today!*

*Also called "deep-hole drills"

Pioneers in the Design and Development of Gun Drills for more than 30 Years

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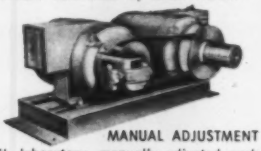
MANUFACTURING CORP.
HAMDEN • CONNECTICUT

Circle 508 on Page 19

KATO VARIABLE FREQUENCY MOTOR GENERATOR SETS
For Better Bench Mock-Up Tests!

AUTOMATIC ADJUSTMENT 360 to 440 CPS

Fully automatic variable frequency motor generator set adjusts 360 to 440 CPS. Generator mounted controls include reset buttons, limit switch. Motor and generator remain stationary. Variable drive pulley adjustment controlled by small motor.



MANUAL ADJUSTMENT

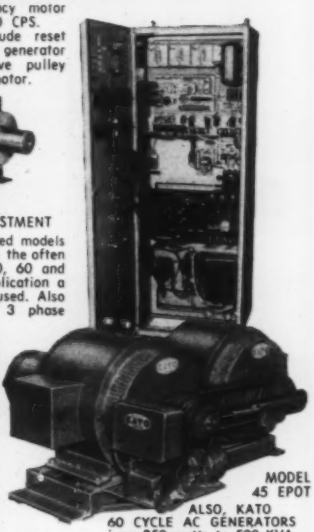
Small, laboratory, manually adjusted models continuously adjustable, permitting the often desired frequencies of 36, 40, 50, 60 and 70 cycles per second. For this application a 1 H.P. direct current motor was used. Also available with single phase or 3 phase motor drive.

CONTROL PANEL

Synchronous motor starter and generator controls including magnetic amplifier, voltage regulator in cabinet.

REMOTE CONTROL

Remote control frequency adjustment varies speed from 1080 to 1320 rpm., thus varying frequency. Bench Mock-Up Test Station may be located anywhere.



MODEL 45 EPOT

ALSO, KATO 60 CYCLE AC GENERATORS from 350 watts to 500 KVA.

WRITE TODAY FOR [illegible] ... IT'S NEW!

BUILDERS OF FINE ROTATING ELECTRICAL MACHINERY SINCE 1928

KATO *Engineering Company* 127 Maxfield Ave. MANKATO, MINNESOTA

Circle 509 on Page 19

When the design calls for an indicating gauge, specify the best-
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New catalog covers gauges for every need
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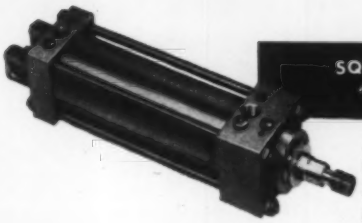
Circle 510 on Page 19

for that
BIG PUSH
LINDBERG HAS THE RIGHT CYLINDER



SQUAREHEAD "S" LINE

A feature packed line with the "quick change" feature • Rated 250 psi for air, up to 1000 psi hydraulic • 7 bore sizes thru 6" • Standardized mounting dimensions.
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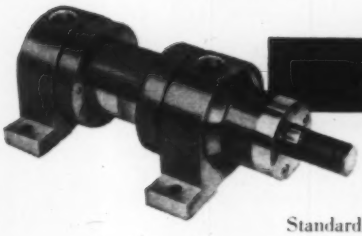
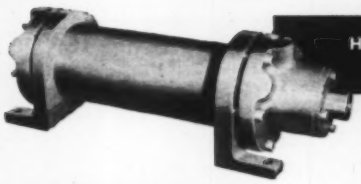


2000 PSI "H" LINE

An extra heavy duty hydraulic cylinder • Available with or without cushions • Standard or 2:1 rods • Bore sizes through 8 inches in 5 mounting styles.
WRITE FOR BULLETIN H-101



HEAVY DUTY "A" LINE

A rugged non-tie rod cylinder for air pressures up to 150 psi and low pressure hydraulic service. Bore sizes through 12 inches • Cushions optional • 5 mounting styles.
WRITE FOR BULLETIN A-101

MEMBER N.F.P.A.

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LINDBERG AIR and HYDRAULIC DIV.
TEER, WICKWIRE & CO.
1877 WILDWOOD AVE., JACKSON, MICHIGAN

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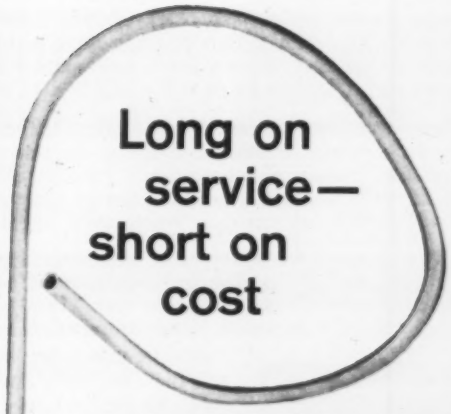

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Alcoa Utilitube and aluminum fittings of several makes are immediately available from stock through Alcoa distributors. The Alcoa sales office listed in the Yellow Pages of your telephone directory can furnish the name of a distributor near you.

Detailed design and specification data are contained in the booklet, *Alcoa Utilitube*. To get your free copy, mail the convenient coupon.

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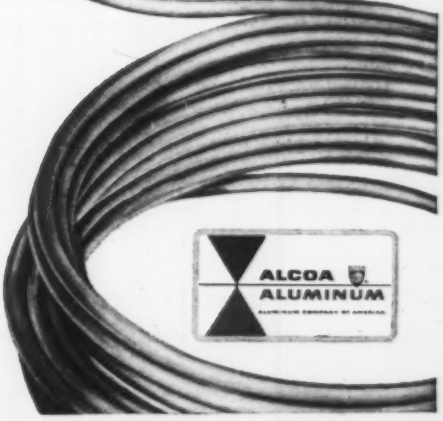


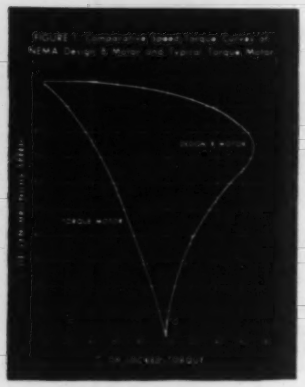
Circle 512 on Page 19

SELECTING TORQUE MOTORS

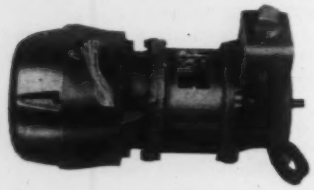
The torque motor, unlike any other electric motor, is a special from the word go. That situation alone makes Peerless one of the best sources for torque motors in ratings from 2 lb. ft. to 200 lb. ft.

Torque motors deliver maximum rated torque without damage to the windings when stalled across the line at full voltage for predetermined periods. Peerless also builds torque motors which provide a nearly constant torque while operating at less than synchronous speeds.

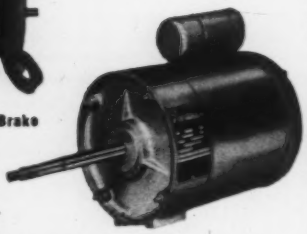
All standard frame sizes; all types of mountings; high torques; special paint and varnish treatments; and Class A, B and H insulation are available from Peerless. Torque motors require unusually close cooperation between the motor supplier and the customer's engineers. This cooperation is a Peerless specialty. We will work with you to produce the one torque motor that powers your product best.



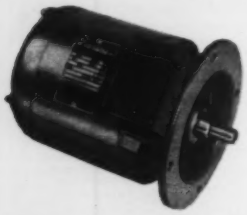
The speed-torque curve varies from that of a conventional motor. The torque motor curve is almost linear. Maximum torque occurs at the stalled position. For this reason, torque motors are used most often where a holding or resisting force is required.



Explosion-Proof Torque Motor With Brake



Special Flange Reversing Hoist Motor Single Phase



Weather-Tight Special Flange

NEW TORQUE BULLETIN

This bulletin outlines basic facts about Peerless torque motors and shows applications. It is available **Free.** Write for it today.

ELECTRIC MOTOR DIVISION

THE *Peerless-Electric*® COMPANY

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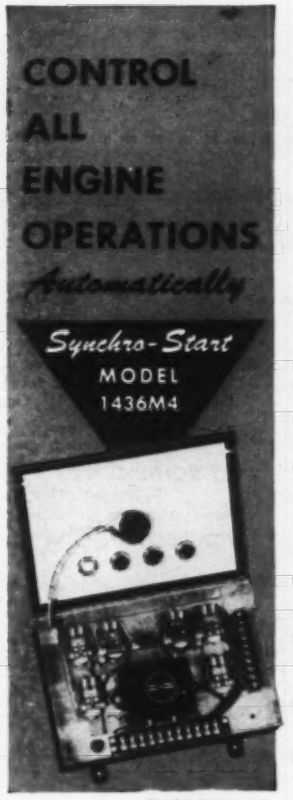

- Full automatic starting from any pilot switch.
- Interrupted cranking with over-all time limit.
- Disconnects starting motor when engine begins to run.
- Three position "AUTO" "MANUAL" "OFF" master control switch.
- Shut-down and individual signal in event of low oil pressure.
- Shut-down and individual signal in event of high water temperature.
- Shut-down and individual signal in event of engine overspeed.
- Failure light in event engine refuses to start.
- Provisions for connecting remote failure alarm.
- Oil pressure time delay to permit starting on zero oil pressure.

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8151 N. RIDGEWAY AVE.
SKOKIE, ILL.

Circle 514 on Page 19

NEW! air duct with highest flame and heat resistance

• A new flexible air duct, type 5J-1D, features high resistance to flame and temperature extremes. Originally designed for air conditioning systems, its heat resistant properties make it ideal for use where internal or ambient temperatures range from −40° to +350°F—as much as +450°F for short durations. In a severe test at 2000°F for four hours, fire was contained within the duct — and, although its tensile strength was reduced, the duct remained intact and prevented the fire from spreading. For details, send for Folder 591 and Data Sheet S-13.

* ***Exclusive construction: The positive mechanical lock unites metal and fabric securely — guarantees long life.***

Wiremold flexible ducts for
air • dust • fumes • materials handling

WIREMOLD® FLEXIBLE AIR DUCT
THE WIREMOLD COMPANY, HARTFORD 10, CONNECTICUT

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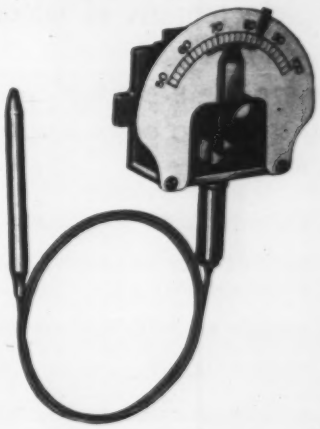
NEW INDICATING TEMPERATURE CONTROL

Range Limits —100 to +600°F **E65N**



New Design gives maximum accuracy at low cost!

The UE Type E65N control is offered in basic skeleton form so that it may be easily incorporated, or designed into equipment, without the need and expense of an enclosure. Enclosures, however, are available upon specification. Setting and indication are clearly visible on a single scale allowing easy reference between the setting and controlling temperatures. Ideal for incubators, centrifuges, oxygen tents, sterilizers, and other applications where it is necessary to control and indicate temperature of gases, liquids and hot plates.

Temperature Ranges	A wide variety of scales between −100 & +600°F.
Thermal Assemblies	Standard 4' capillary with several bulb styles and sizes.
Operation	Liquid filled bellows assembly expands or contracts with heating or cooling thus actuating a snap-acting electrical switch at desired control point.
Switch Ratings	15 amps 115/230 volts AC. DC and other special switches available.
Switch Actions	Normally closed; normally open; and double throw, no neutral position.
Electrical Connections	Lead wires attached to terminal on switch.
Size & Weight	1 lb; scale plate 4½" wide.
Variations	Design variations available on request.

UNITED ELECTRIC *manufactures a complete line of temperature, pressure and vacuum controls. For application requiring custom-built units or modified standard units, call upon a UE application engineer for recommendations. Request Type E65N Design Catalog Sheet for complete specification and pricing data and for information regarding other United Electric temperature controls.*

United Electric Controls
COMPANY
85 SCHOOL STREET WATERTOWN MASS.

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How to increase product reliability by eliminating the loose fastener problem

Use UNBRAKO self-locking socket screws to keep your assemblies tight

With the Missile Age has come the realization that as mechanisms become more complex and automatic, every part must have a high degree of reliability, regardless of size or function, no matter how insignificant it may seem.

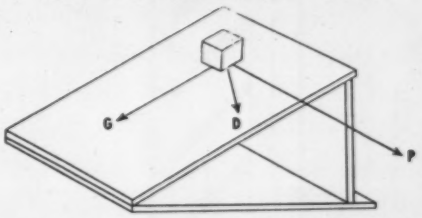
Most product mechanical failures occur at or around joints—the points of high stress concentrations. Threaded fasteners are widely employed to secure joints because they usually must be designed for disassembly as well as assembly. Far too frequently, however, they vibrate loose, acting more like "threaded looseners," and causing equipment malfunction, breakdowns and customer complaints. In some instances—ordnance or aircraft, for example—the consequences can be disastrous.

UNBRAKO socket screws with the Nylok* self-locking feature offer you a simple, practical solution to this problem. An UNBRAKO with Nylok is a single, self-locking unit requiring no auxiliary locking devices, no extra time or labor to install. The tough, resilient nylon pellet forces mating threads tightly together, locking the screw securely, seated or not, wherever wrenching stops. It will not work loose, despite severe vibration. Furthermore, a self-locking UNBRAKO can be used repeatedly. In contrast, lockwashers sometimes snap or lose their spring if frequently tightened; and a cotter pin cannot safely be used more than once.

Off the shelf, a self-locking UNBRAKO may cost slightly more than an ordinary fastener. But f.o.b. your product, it usually costs less . . . assembly time, labor and reliability factor considered. See your authorized SPS distributor for complete details. He carries a full line of UNBRAKO self-locking products. Or write us for literature and samples. Unbrako Socket Screw Division, STANDARD PRESSED STEEL CO., Jenkintown 18, Pa.

*T.M. Reg. U.S. Pat. Off., The Nylok Corporation

HOW A SCREW WORKS LOOSE



The reason why a screw works loose under vibration is best explained by the analogy of a free block on an inclined plane, illustrated above. The slope is such that friction keeps the block from sliding (G). But if an external force starts to move the block sideways (P), friction can be reduced to the point where the block begins to slide down at the same time (D). A similar action takes place with screw threads. Tightening the screw forces the thread "uphill" against the thread of the nut or tapped hole. This sets up tension in the screw, creating enough friction between mating threads to hold it tight—under some conditions. Often, however, vibration causes marked variations in screw tension, resulting in motion between mating threads to the point where they begin to slip past one another or "run downhill." The result: a threaded loosener.

LOCKED! The tough, resilient nylon pellet—permanently installed—keys itself into mating threads, forcing them tightly together and locking the screw securely. Self-locking UNBRAKOS will not work loose, despite severe vibration.

hiR High Reliability factor

At SPS we apply a dynamic standard of quality—continually refined—so that our fasteners will always have the high reliability factor required by today's faster speeds, higher temperatures, and greater dynamic forces. By using SPS fasteners in your assemblies, you increase overall reliability—the certainty of predictable performance under actual service conditions.

For more information on the science of reliability—the newest branch of product engineering—write for a copy of the SPS booklet "Concerning High Reliability"—just published.

We also manufacture precision titanium fasteners / write for free booklet

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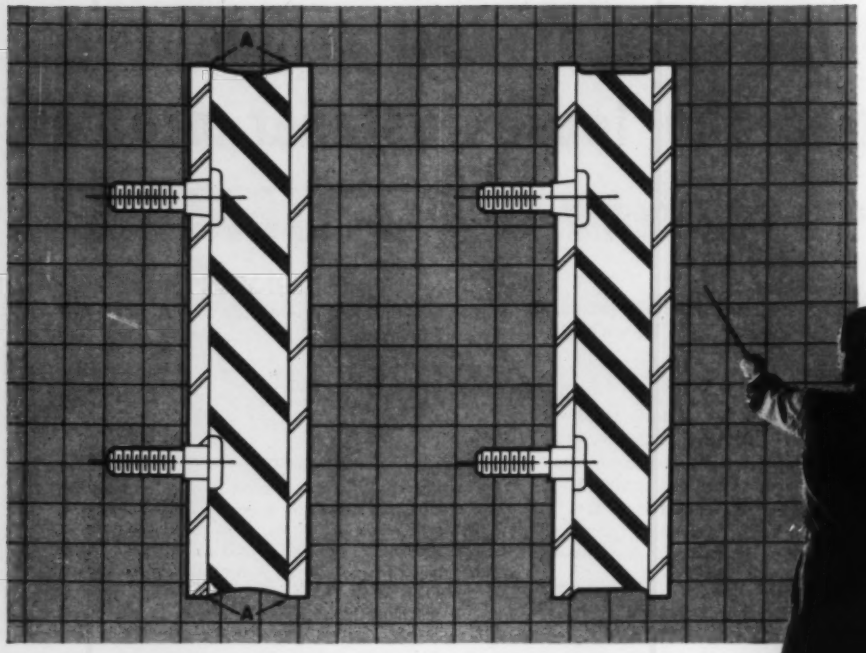


Savings in molded rubber parts begin with improved design

thru **ORCO**

CUSTOMEERING

Similar designs? Almost, but not quite. In the design at left, "A" is a stress point. The shrinkage of the rubber can cause concentrated strain at the edges of the bonded area. Ohio Rubber engineers would probably recommend the design shown at right.

Attention to important details like this is typical of ORCO's "customeering" of parts made from rubber, synthetic rubber, silicone rubber, polyurethane, and flexible vinyl, whether they be molded, extruded, or bonded to metal.

From components weighing less than a gram to parts of over 73 lbs., whatever the shape involved, ORCO's integrated research, design, electronically controlled compound mixing, and production facilities, assure component uniformity and quality to meet the most exacting requirements. Check with ORCO engineers on your next rubber or vinyl component problem. Your inquiry will receive prompt attention.

Send for free booklet "Component CUSTOMEERING rubber and vinyl parts".

THE OHIO RUBBER COMPANY

A Division of The Eagle-Picher Company
Willoughby, Ohio

Circle 518 on Page 19

FARVAL—*Studies in Centralized Lubrication*
No. 218

Farval lubrication first choice for Hill-Acme Upsetter

On this 1¼-inch Hill-Acme Upsetter, Farval's timing cycle can easily be changed to conform with the service of the machine. Amount of lubricant delivered to each bearing is also adjustable.

BUILDING peak performance into their machines is a point-of-pride with Hill-Acme. That's why you'll find Farval lubrication systems on H-A machines such as this upsetter.

When the going's rugged, with shock, vibration and wear trying to take their toll, Farval continuously guards 59 vital bearings . . . continuously delivers measured amounts of lubricant at regular intervals.

More and more, machine designers, engineers and production men are turning to Farval for the kind of lubrication that spells uninterrupted, maintenance-free production. Let us tell you more. Write for Bulletin 26-S. The Farval Corporation, 3287 East 80th Street, Cleveland 4, Ohio.

KEYS TO ADEQUATE LUBRICATION

Wherever you see the sign of Farval—familiar valve manifolds, dual lubricant lines and central pumping station—you know a machine is being properly lubricated.

Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing. In Canada: Peacock Brothers Limited.

Circle 402 on Page 19

The world's finest machines are controlled from Cutler-Hammer oil-tight pushbutton Control Stations

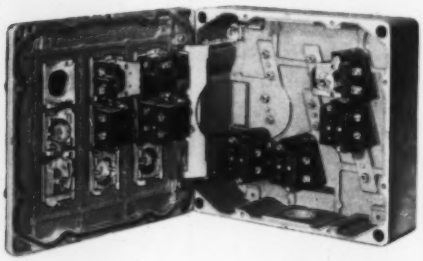
The Cutler-Hammer line of heavy duty oil-tight pushbuttons and precision die-cast control stations surpass anything ever before available to serve the needs of machine design engineers. Cutler-Hammer Oil-Tight Control Stations are precision die-castings to permit both base and one-hole mounting of the control units. The one to four element control stations are available in either the normal depth or the exclusive shallow depth for use where space limitations are critical.

Cutler-Hammer Pushbutton contact blocks are easily tandem mounted without special adapters, and use less behind-the-panel space than any other. Circuits can be arranged in any combination of NO and NC contacts.

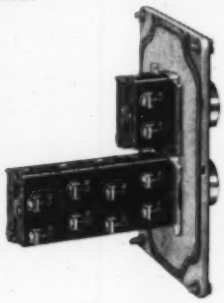
Indicating lights come in a wide selection of colors with either plastic or glass lenses. Among the many special operators are: Roto-Push®, the combination pushbutton-selector switch; PresTest®, the self-testing indicating light; knob, key, lever, and coin type selector switches; flush, long, mushroom head, guarded, and palm type pushbutton operators.

For further information, write on your company letterhead for the C-H Master Design, Publication EL-178.

. . . CUTLER-HAMMER Inc., 1310 St. Paul Ave., Milwaukee 1, Wis. Associate: Canadian Cutler-Hammer Ltd., Toronto.

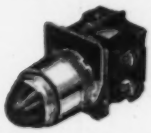


The hinged cover on the larger Oil-Tight Control Stations facilitates assembly and alterations. Precision die-castings permit both base and one-hole mounting of the control units. Raised edge on the box mates with the neoprene-cork cover gasket for a perfect seal.



Complete line of cover plates for cavity mounting. Compact contact blocks take 40% less space behind the panel than the next smaller element . . . additional blocks easily tandem mounted . . . from 2 to 8 separate circuits in any combination of NO or NC contacts.

Special Purpose Operators and Accessories



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Selector switches—knob, lever, key, coin

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